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AD NUMBER
ADC000424
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TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
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(1)

TECHNICAL REPORT
HCI-CMC-18540

TRANSMISSION LOSS OF LOW FREQUENCY UNDERWATER SOUND IN THE CAYMAN TROUGH (CHURCH GABBRO TECHNICAL NOTE) (U)

by

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JUNE 1974

PREPARED FOR THE LONG RANGE ACOUSTIC PROPAGATION PROJECT, OFFICE OF NAVAL RESEARCH, CODE 102-OSC, UNDER CONTRACT NO. N00014-67-A-0201-0024; NR 292-117/9-25-72.

CLASSIFIED BY DD FORM 254, DTD 1 SEPTEMBER 1972
CONTRACT NO N00014-67 A-0201-0024
SUBJECT TO GENERAL DECLASSIFICATION
SCHEDULE OF EXECUTIVE ORDER 11652
AUTOMATICALLY DOWNGRADED AT
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TRANSMISSION LOSS OF LOW FREQUENCY UNDERWATER SOUND IN THE CAYMAN TROUGH (CHURCH GABBRO TECHNICAL NOTE)

By

Scott C. Daubin

0. Executive Summary

(C) Acoustic propagation loss experiments were conducted in the Cayman Trough of the Caribbean during November and December 1972, as part of the CHURCH GABBRO exercise, sponsored by the Long Range Acoustic Propagation Project of the Office of Naval Research. Two forms of acoustic sources were employed: underwater explosive sources, SUS Mk 61-0 and Mk 82-0; and towed CW projectors, a piezoelectric source designated HX 231 F and a hydromechanical source designated VIBROSEIS. A total of 1106 SUS charges were dropped from two shipboard runs and 478 SUS charges were dropped from aircraft in one run having four segments. CW acoustic sources were unreliable and intermittent; this report covers only results of the explosive sources. Shipboard runs from the northeast to the southwest ends of the Cayman Trough were received at two locations by Acoustic Data Capsule (ACODAC) systems. One was located near the middle of the trough, about 140 nautical miles WNW from Montego Bay, Jamaica; another was located in the far southwest end of the trough. Each ACODAC sampled the SOFAR Channel from near the axis to the critical depth with six hydrophones. Aircraft runs were received by a Tethered Acoustic Buoy System (TABS) and two SONOBUOYs located at a position approximately midway between the ACODACs. Three organizations were involved in the reduction of data: the Woods Hole Oceanographic Institution, the University of Texas/Applied Research Laboratory, and the Naval Underwater Systems Center/New London Laboratory. The data reduction methods employed by each organization are described. Transmission loss results are dominated by the effects of topography. In the short ranges from the southwest measurement point (out to 160 nautical miles) a complete SOFAR channel exists, but the convergence zone structure which would be expected in the open ocean is smoothed by the large amount of reflected energy from the lateral topography. At long ranges (beyond 450 nautical miles) the intermediate ridge structure baffles the acoustic energy, but as range increases out to 600 nautical miles this effect is offset by others, such as bathymetric focussing, which result in an anomalous curve, i.e., the reduction of transmission loss with increasing range. One of the objectives of the exercise was to search for depth dependence in transmission loss. A very sharp depth dependence was found, sometimes as high as 10 db between adjacent hydrophones, but this effect was intermittent and a strong function of range, occurring in a regular pattern relative to the positions of the convergence zones. In general the largest signals were received in the vicinity of the critical depth.

1. Introduction

1.1 Experiment

(C) In November and December 1972 the Long Range Acoustic Propagation Project (LRAPP) sponsored an exercise at sea in the general area of the Cayman Trough of the Caribbean. Among the objectives of the exercise were the measurement of environmental acoustic variables during this seasonal period. For a detailed description of the plan and an outline of the preliminary results, see References 1 and 2 respectively. Key locations of the exercise are shown in Figure 1. Acoustic Data Capsule (ACODAC) units were located at Positions B and D; one was also located at Position H but produced no data. A Moored Acoustic Buoy System (MABS) was located at Position A; aircraft sonobuoys were located in the vicinity of Position D and at Positions S-1 through S-8 in sequence. All of the systems enumerated above measured ambient noise which has been reported in Reference 3. Explosive signals for the purpose of transmission loss measurements were also measured by the ACODACs and by a Tethered Acoustic Buoy System (TABS) and two sonobuoys located at Position C.

(U) Two ship SUS runs were conducted by R/V NORTH SEAL; the first on 4-5 December 1972 was along a great circle from Point E to Point B, and the second on 8-9 December 1972 started from a position 60 miles ENE of Position C and proceeded to Position D. See Figure 2. On both runs NORTH SEAL dropped Mk 82 Signals Underwater Sound (SUS) set to explode at a depth of 91.4 meters. On 7 December 1972 an aircraft from VXN8 conducted a SUS run traversing the following track: E-D, D-G, G-B, B-H, H-D and D-E; see Figure 3.

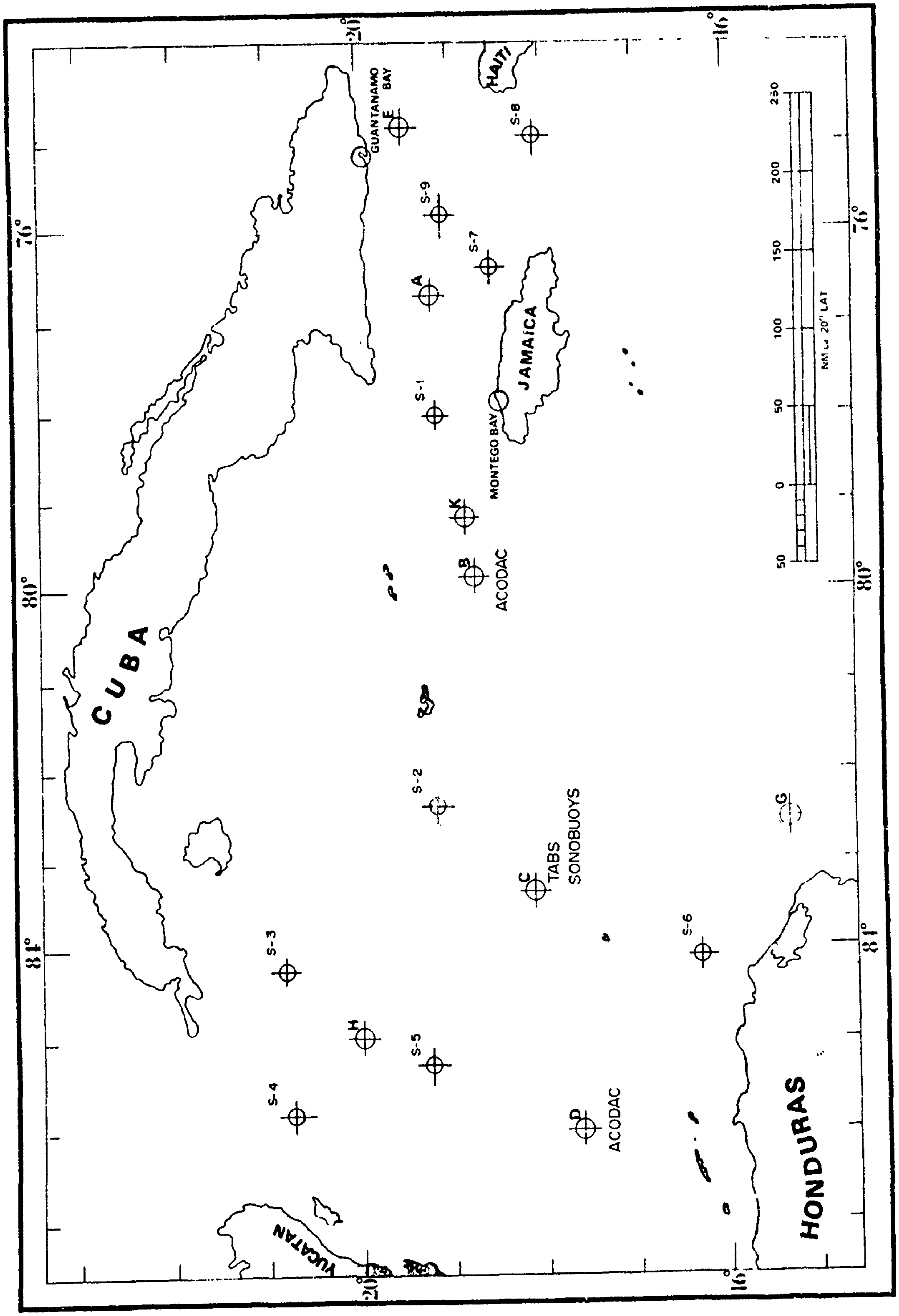
(U) The aircraft dropped Mk 61 SUS set to detonate at 18.3 meters during the southwesterly legs E-D, D-G, G-B, B-H, and at 91.4 meters during the northeasterly legs, H-D and D-E.

(C) This report covers the transmission loss calculations derived from the SUS runs; data are plotted only in the 50 Hz 1/3 octave band for ACODAC measurements but in the 25 Hz, 50 Hz, 100 Hz, 160 Hz, 200 Hz, 400 Hz and 800 Hz 1/3 octave bands for the TABS and SONOBUOY measurements.

1.2 Experimental Systems

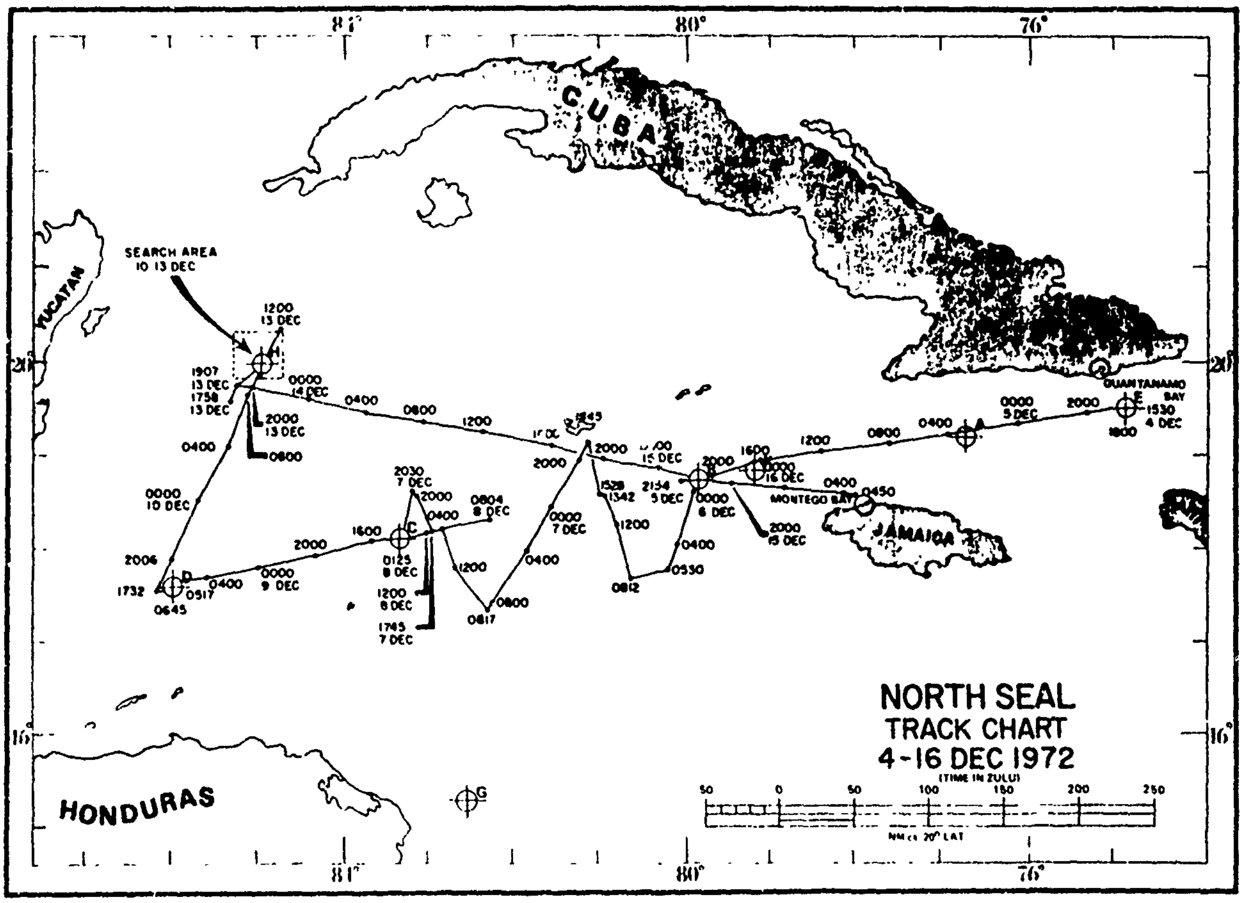
1.2.1 General

(U) Reference 3 describes in some detail the systems employed in this exercise and discusses the performance of each. This section recapitulates the main system structure of the experiment. In general these systems may be divided into three categories: sources, receivers and vehicles. Characteristics of sources and receivers of acoustic energy are outlined in Section 1.2.2 below. Vehicles included surface vessels which deployed receiving systems, towed or launched sources and aircraft which dropped SUS charges or sonobuoys or conducted ship surveillance. All ships and aircraft squadrons also measured environmental data. These vehicles included USNS SANDS (T-AGOR-6) operated by MSTS for NUSC, which deployed



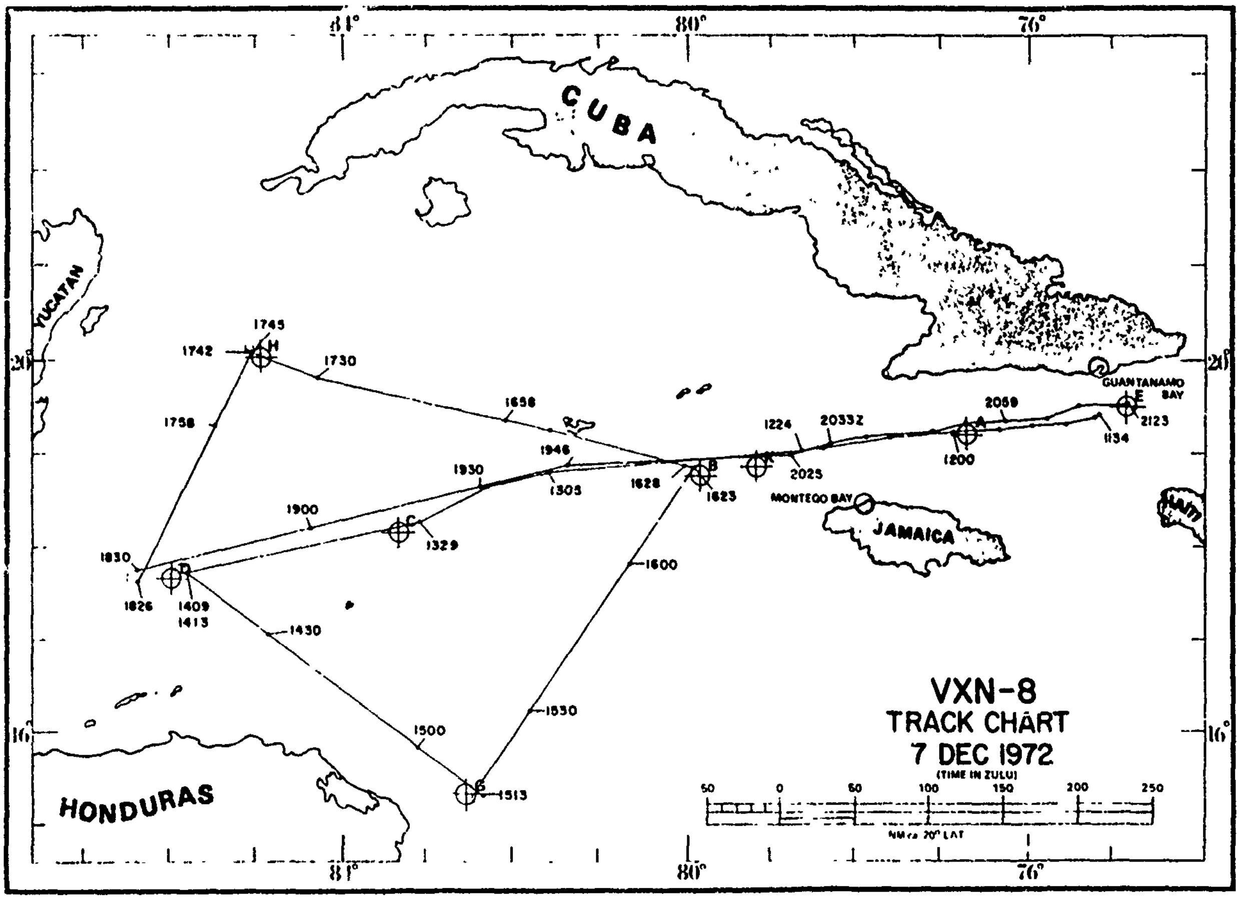
(U) CHURCH GABBRO Area Chart

Figure 1



(U) NORTH SEAL Track Chart
4 - 16 Dec

Figure 2



(U) Actual Track of Air Dropped SUS

Figure 3

MABS, TABS and sonobuoys and towed the HX 231 CW source; R/V NORTH SEAL, operated by Texas Instruments, Inc. under MSTS contract for the LRAPP office, which deployed ACODACs and SUS charges; MS DEARBORN, operated by Delta Exploration Co., which towed a CW source; VXN-8; experimental aircraft squadron operating for the Naval Oceanographic Office, which conducted ship surveillance, monitored sonobuoys for ambient noise and dropped SUS charges and VP 16, operational patrol squadron which conducted ship surveillance.

1.2.2 Sources and Receivers

(U) Two types of sources were employed: CW and SUS (Signal Underwater Sound). Two CW sources were used: VIBROSEIS towed by MS DEARBORN and HX 231 F towed by USNS SANDS. VIBROSEIS is a hydromechanical CW source of tunable frequency and controllable level; two projectors were towed, one at 18.3 meters and one at 91.4 meters. The operating schedule for this exercise is given by the table below:

18.3 meters	91.4 meters	Time On
12 Hz	15	4.5 minutes
15	12	4.5 minutes
20	25	4.5 minutes
25	20	4.5 minutes
32	40	4.5 minutes
40	32	4.5 minutes
50	63	4.5 minutes
63	50	4.5 minutes
80	100	4.5 minutes
100	80	4.5 minutes

Table I

(U) VIBROSEIS FREQUENCY/DEPTH SCHEDULE

(U) HX 231 is a piezoelectric CW source whose dual frequencies were set at 85 Hz and 128 Hz. HX 231 F was to be towed at 300 meters. Unfortunately neither VIBROSEIS nor HX 231 F worked well during the experiment. For a description of the operational experience with these systems see References 2 and 3. In view of the sparse data density the CW data have not been analyzed for transmission loss.

(U) Two types of Signal Underwater Sound (SUS) were employed: Mk 61-0 and Mk 82-0. Their characteristics are outlined below:

	Mk 61-0		Mk 82-0
Weight (lbs)	6.8	.....	6.8
Firing Depth (M)	18.3 243.9	....	18.3 91.4
Sinking Rate (Term.Vel.) (M/S)	5.1	.....	5.1
Arming/Firing Mechanism (Mark)	33-0	.....	39-0
Explosive Section (Mark)	4-0	.....	4-0
Explosive Weight (lbs) and Type	1.8 TNT	.....	1.8 TNT
Booster Weight (Oz) and Type	1.1 TETRYL	.....	1.1 TETRYL
Lead-In Cup Weight (grams) and Type	0.218 TETRYL	.....	0.218 TETRYL
Detonator (Mk)	43-1	.....	43-1
Arming Depth Min. (M)	5.5	.....	5.5
Launching	Air/Surf	.....	Air/Surf
Purpose	Service	.....	Oceanographic R&D

Table II

(U) SUS DETAILS

During the exercise NORTH SEAL dropped a total of 1106 Mk 82-0 SUS charges, aircraft of VXN-8 dropped a total of 302 Mk 61-0 SUS charges and 176 Mk 82-0 SUS charges.

(U) Receivers employed in measurement of SUS signals from which transmission loss data were derived included two ACODACs, one TABS and two sonobuoys. ACODACs measured simultaneously from six hydrophones located at various depths throughout the water column; TABS sampled two depths and sonobuoys were configured for deep or shallow measurement. The locations and sampling depths are indicated below:

System	ACODAC	ACODAC	TABS	SONOBUOY
Position	B	D	C	C
Latitude	18° 49.0' N	17° 34.3' N	18° 18.0' N	18° 18.0' N
Longitude	79° 52.7' W	86° 00.5' W	83° 22.0' W	83° 22.0' W
Mooring Type	Compliant	Armored	NA	NA
Hydrophone Depths (Meters)	966	508	244	18.3
	1576	1119	396	91.4
	2757	2341		
	4410	4043		
	4715	4358		
	4806	4450		
Mixed Layer	60	60	60	60
Axis	1050	960	1000	1000
Critical Depth	4510	4510	4460	4460
Bottom	4833	4509	5220	5220

Table III

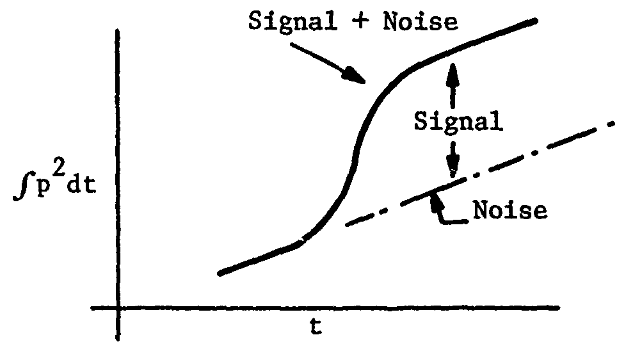
(C) ACOUSTIC SAMPLING POINT AND SOUND CHANNEL DATA

2. Data Processing

2.1 ACODAC

2.1.1 Woods Hole Hand Analog Method

(U) This method employs an analog integrator and a chart recorder. A human operator is an essential part of the loop. The system is shown in block diagram form in Figure 4. The operator listens to the tape for the arrival of a shot and notes the footage of the beginning of the signal. He then backs up the tape and runs it again, this time starting the integration at a time sufficiently ahead of the onset of the shot to permit a determination of the *a priori* ambient noise power. He also terminates the integration after the signal has disappeared into the noise long enough to obtain a post signal measurement of ambient noise. The power of the received signal plus noise or noise alone is determined by the slope of the integral curve as plotted on the graphic record. The typical shot is in the form of an "S" curve; the lower left and upper right tails of which represent the pre-shot and post-shot noise respectively. The vertical distance between parallel lines drawn through these two tails represents the total shot signal energy received. This process is indicated in the sketch below which represents the output of the integrator:



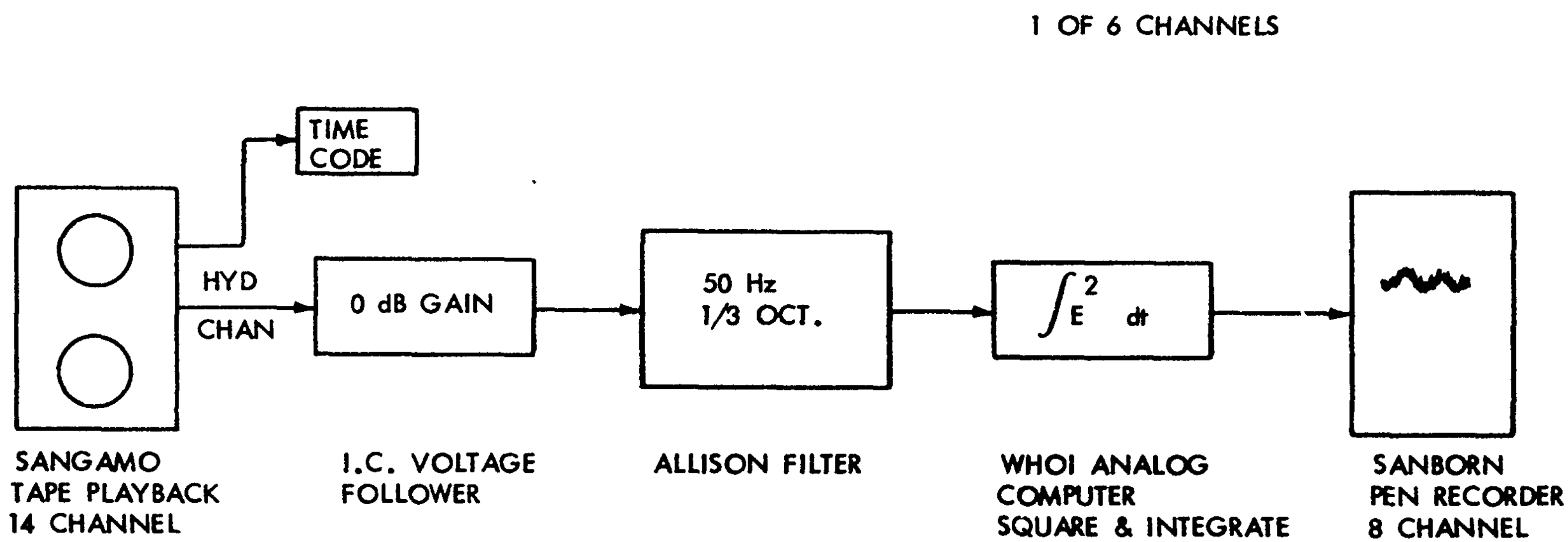
The mathematics of the process is outlined below. If p_{s+n} represents the sound pressure level of the shot signal plus noise and p_n represents the sound pressure level of noise alone, the energy received in the shot signal E_s is given by:

$$E_s = \frac{1}{\rho c} \int [p^2_{s+n} - p^2_n] \, dt$$

where ρc is the acoustic impedance of the medium at the hydrophone.

If V represents the voltage at the output of the complete signal processing system at the input to the squaring circuit, it is related to the sound pressure level at the hydrophone by:

$$V = S\,G\,C\,p$$



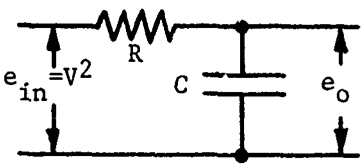
(U) Analog Computer System
(WHOI)

Figure 4

where S is the hydrophone sensitivity, G is the total ACODAC system gain and C is the transfer calibration which relates a recording level to a playback level. Then

$$E_s = \frac{1}{\rho c\ S^2 G^2 C^2} \int (V^2_{s+n} - V^2_n)\ dt$$

If V^2 represents the input to an RC integrator as shown in the figure where $RC \gg 1/\omega$ the output of the integrator is approximated by:



$$e_o = \frac{1}{RC} \int V^2\ dt$$

We now have a measure, expressed in db re ergs/cm^2 of the shot signal energy received:

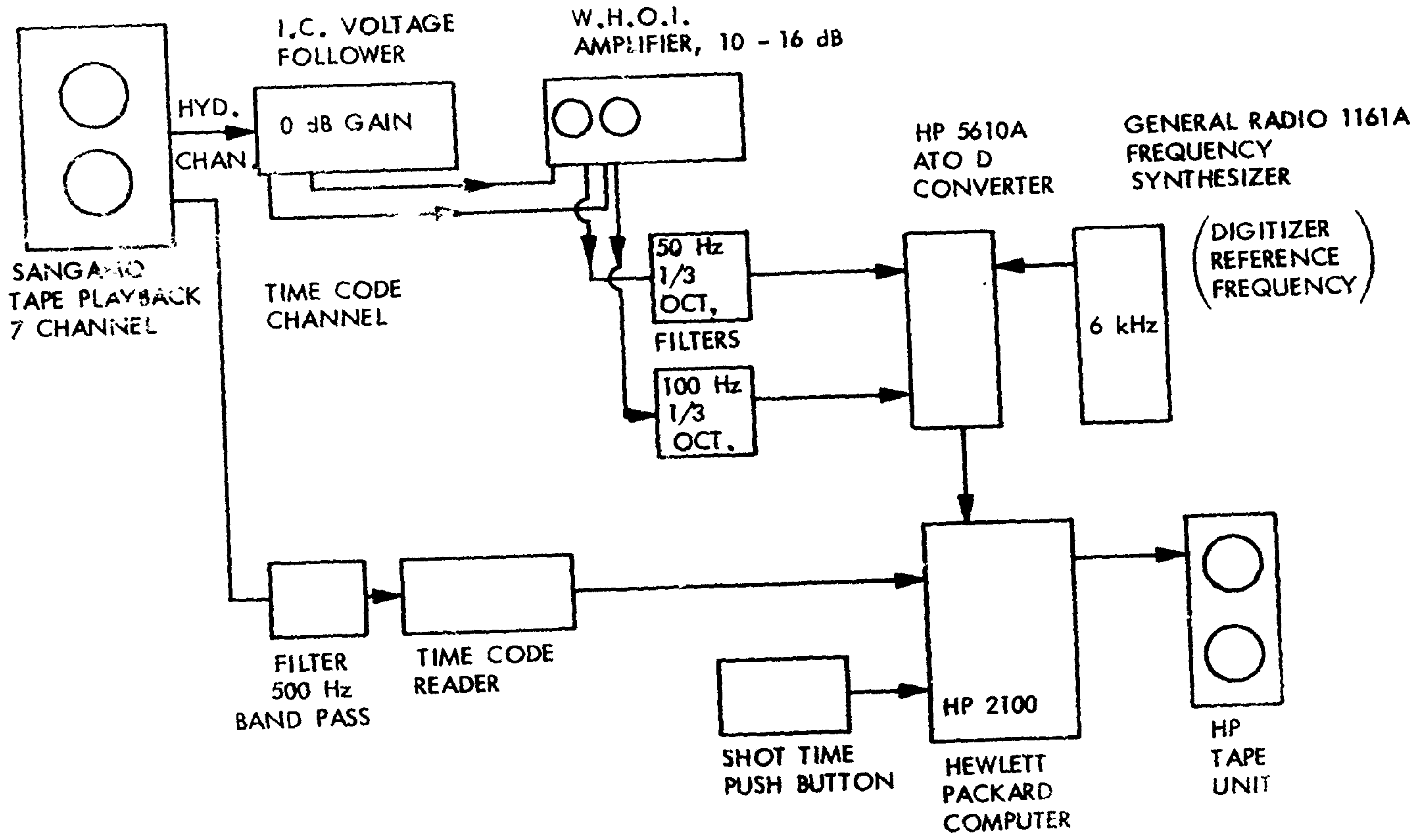
$$10 \log E_s = 10 \log RC - 10 \log \rho c - 20 \log S - 20 \log G - 20 \log C + 10 \log (e_{o_{s+n}} - e_{o_n})$$

2.1.2 Woods Hole Semi-Automatic Digital Method

(U) The Woods Hole digital method is shown in Figures 5 and 6 and is described in Reference 8. It is called "semi-automatic" here because although many inputs and all computations are automatic, an operator is required as part of the processing loop. In the first pass, shown in Figure 5, the analog tape is played back in a 20:1 time compression ratio through isolation circuitry, amplifiers and 1/3 octave filters to an A/D converter and then into the buffer of a digital computer. An operator, listening for shots through a loudspeaker (not shown), starts the computation process when a shot is detected. The computer, which has a loaded buffer of a priori noise, commences squaring and integrating first the noise, then the signal plus noise and finally again the noise alone when the signal energy disappears. The output integral is recorded as a function of time on digital tape. In the next pass, shown in Figure 6, this digital tape is run through the shot energy computation process and the output, again recorded on digital tape, represents shot energy, noise, and shot time. In this pass the integral "S" curve is displayed on an oscilloscope. The operator positions cursors which define that portion of the a priori noise to be used as a noise estimator during the shot, the shot arrival time and the shot computation time. During this process the computer generates and displays a second, integral from which the noise estimate has been removed.

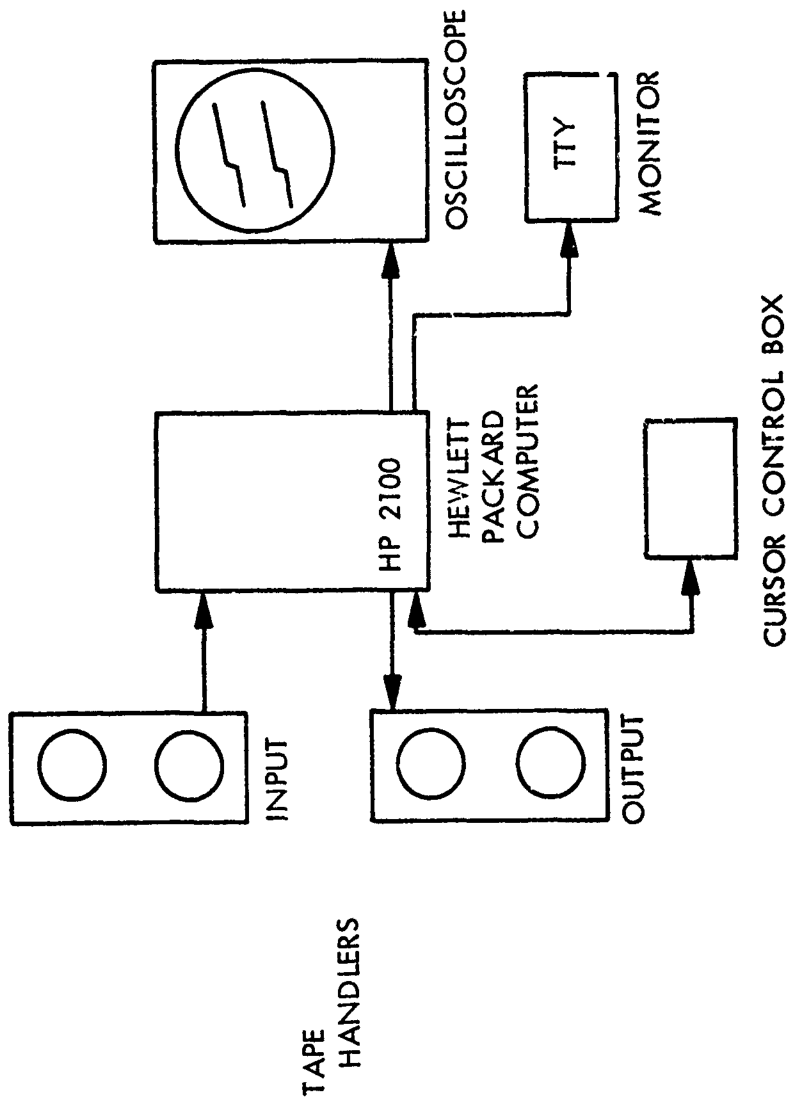
2.1.3 University of Texas Automatic Digital Method

(U) Automatic computer processing of SUS runs was conducted by the Applied Research Laboratory of the University of Texas at Austin (UT/ARL). The system was programmed to recognize the occurrence of a shot and to process it digitally, deriving the energy in six 1/3 octave bands with center frequencies



(U) Digital Shot Processing System
Shot Digitizing Schematic
(WHOI)

Figure 5



(U) Digital Shot Processing System
Shot Processing Schematic
(WHOI)

Figure 6

at 12.5, 25, 50, 100, 158.5 and 200 Hz. The process takes place in three Phases[1]. Refer to Figures 7, 8, and 9. In Phase I three ACODAC data channels along the time code, gain states and overload information are sampled and the quantized data are output onto digital tape. Usually 24 hours of ACODAC time are placed onto 10 digital tapes in one operation.

(U) Phase II begins when the data are on digital tape. A few selected shots are detected and plotted for visual inspection. The visual inspection verifies the shot pattern and determines the integration times necessary to cover a shot. Concurrent with the visual inspection the parameters for the shot detector are chosen. The shot detector is a computer sub-program which searches the data for the start time of a shot and outputs the time to within 0.01 second.

(U) After this initial inspection the main shot processor program is started. The program searches the digital tapes, locates the shots, computes the shot energy in 1/3 octave bands (via an FFT) and outputs the energy (in units of computer numbers) along with time of detection onto another digital tape.

(U) In addition a noise estimate for each shot is made 15 seconds before the detection time. The overloaded data are ignored. Concurrent with the shot processing program the 6-hour calibrations are processed which were the only system frequency response available for CHURCH GABBRO. Frequency corrections were made to the data by a straight line interpolation between the 50 and 200 Hz levels. Phase III begins after the shot and calibration processing is complete.

(U) The last step is Phase III; it is mainly an editing program. Given the calibration level, ρc, hydrophone sensitivity and system frequency response (including that of the hydrophone), range and shot detonation times, the final program edits out false alarms and scales the final results to acoustic energy in db re ergs/cm^2/Hz for shots and db re uPa^2/Hz for noise power. The results are placed onto digital tape, plotted and tabulated.

2.2 TABS and SONOBUOY[2]

(U) All received acoustic signals and calibration signals were recorded on magnetic tape. The wide band recorded signals from each hydrophone (both high and low gain) were fed into an Ithaco amplifier and then through a B & K 1/3 octave filter bank with continuous bands from 25 to 1000Hz. Each filter output was then fed into an envelope detector/averager, the output of which was serially sampled, multiplexed, and finally converted from analog values to 12 bit digital words. To assure proper alignment of the acquisition window and the received data, a graphic recorder was used to

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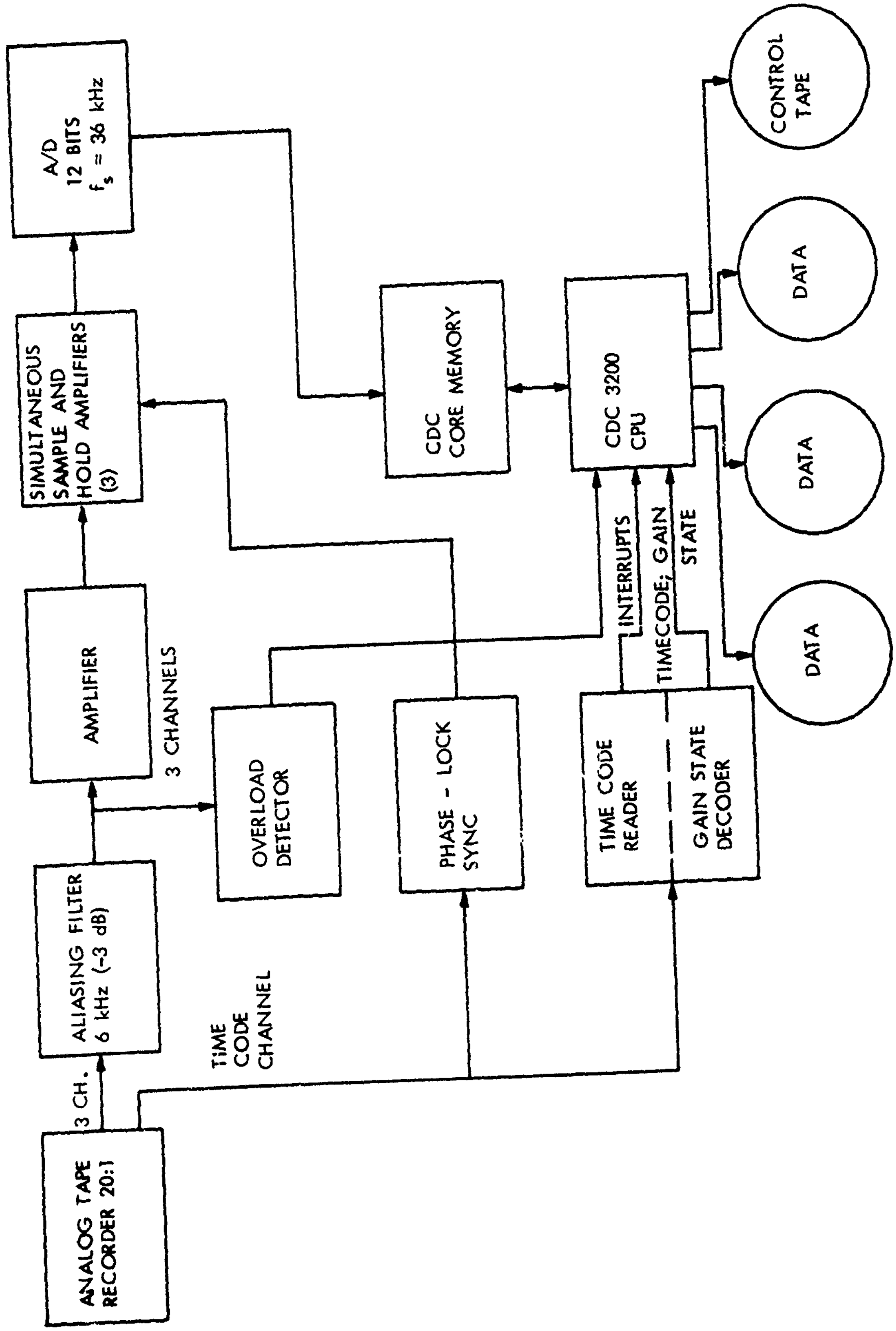
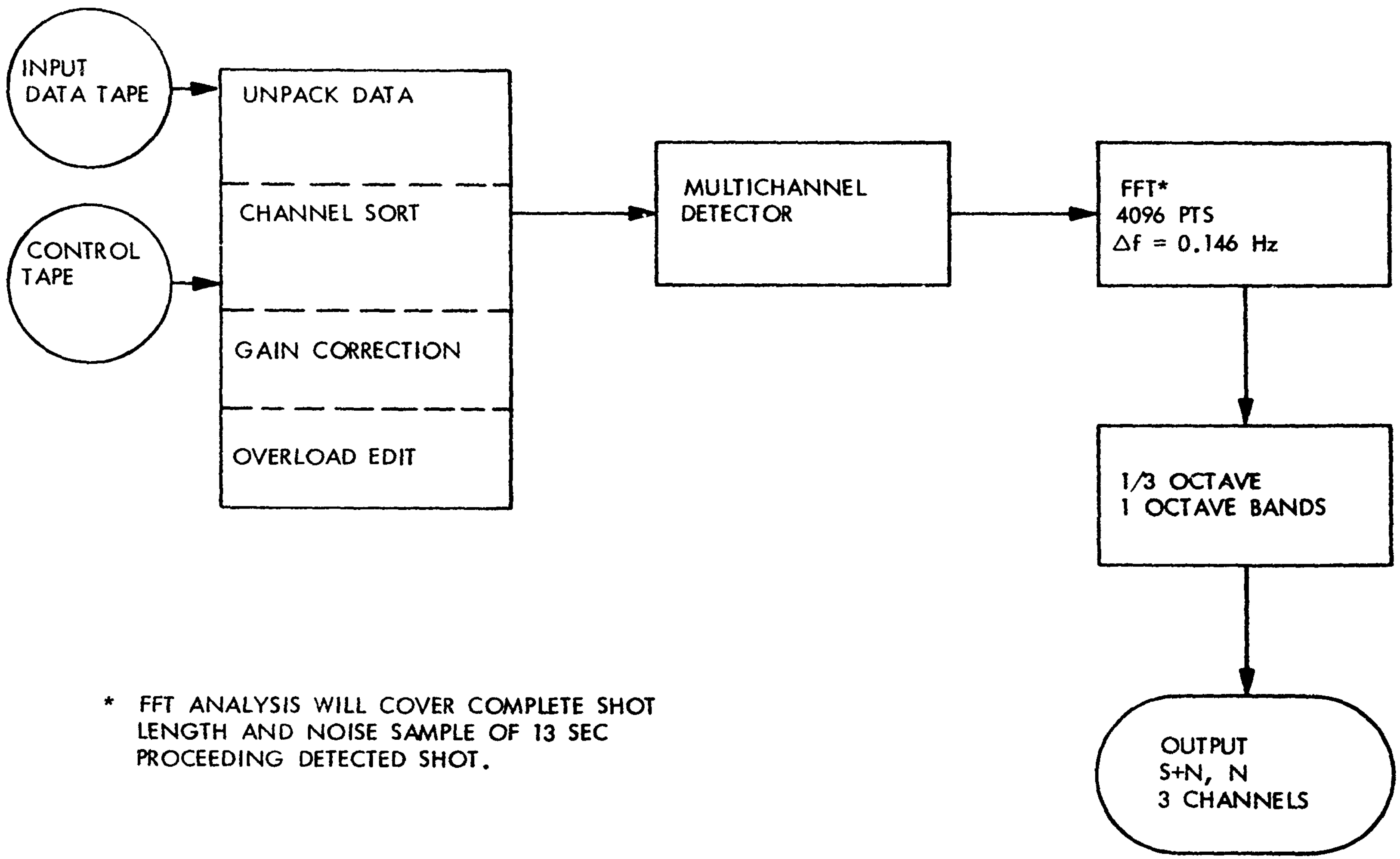
[1] The information on the UT/ARL processing method was provided by Mr. Jack A. Shooter in a letter to S. C. Daubin, University of Miami, Ser F-689 dated 21 January 1974. The description of the system is copied almost verbatim from this letter.

[2] This information was supplied by Mr. Robert F. LaPlante at NUSC/NLL. This section is repeated almost verbatim from Mr. LaPlante's report.



(U) Shot Processor Phase I
(UT/ARL)

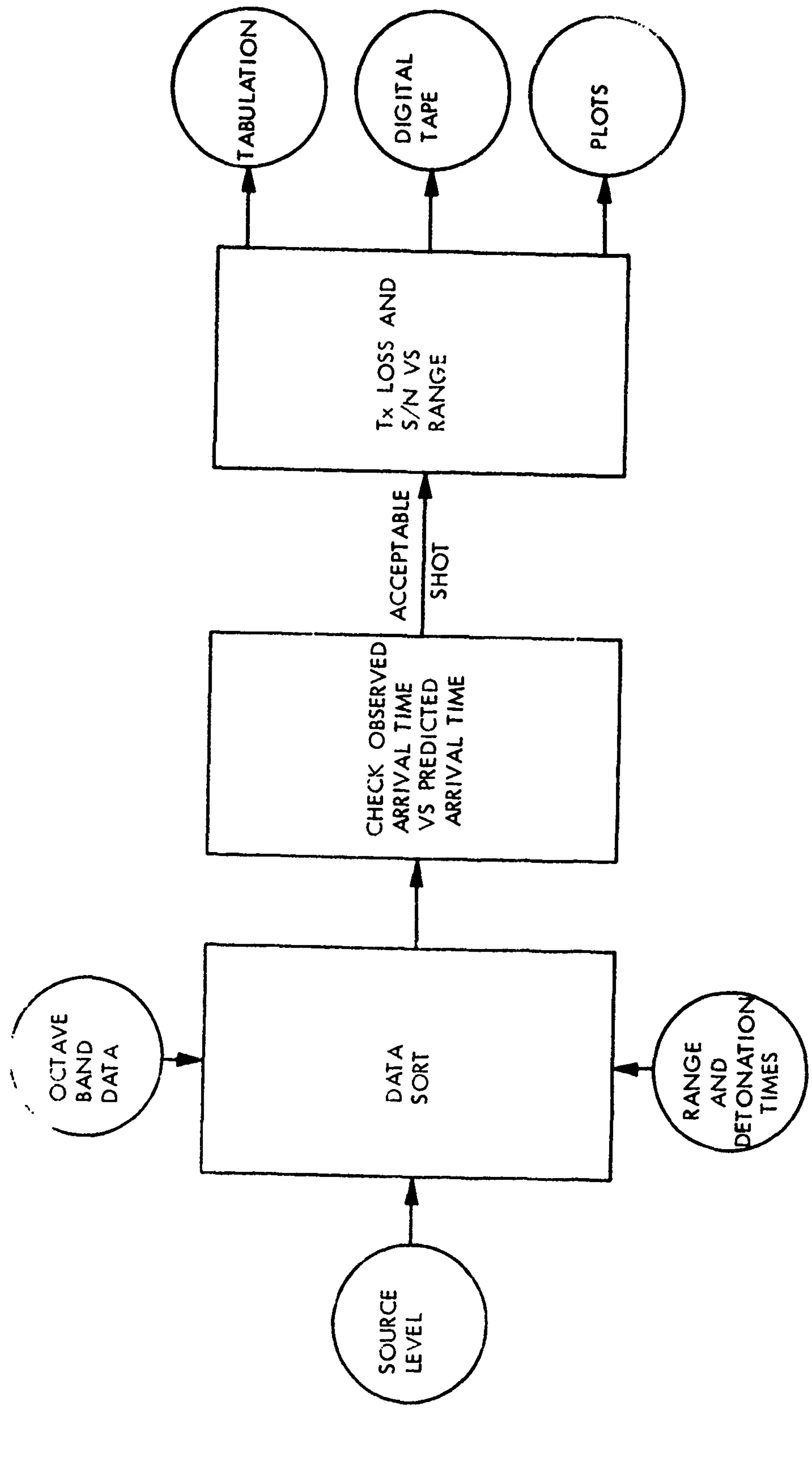
Figure 7



* FFT ANALYSIS WILL COVER COMPLETE SHOT LENGTH AND NOISE SAMPLE OF 13 SEC PROCEEDING DETECTED SHOT.

(U) Shot Processor Phase II
(UT/ARL)

Figure 8



(U) Shot Processor Phase III
(UT/ARL)

Figure 9

monitor both the analog signal and the computer generated window. In addition, a peak detector was utilized to determine signals that were overloaded on magnetic tape. A diagram of the above system appears in Figure 10.

(U) Prior to each group of SUS arrivals, a ten second sample of noise was sampled, digitized, and normalized to one second. The SUS signals were sampled from 8 seconds to 45 seconds depending on the duration of the signal arrivals. This sampling duration was predetermined by observing graphic traces.

(U) The digital samples were inputs to the UNIVAC 1230 computer, where a computer program squared and integrated both the noise samples and the SUS generated signals., See Figure 11. The program also computed energy propagation loss, spectrum noise levels, signal-to-noise ratios, peak propagation loss and received band level. These values, along with integration time, SUS arrival time and consecutive SUS number were printed as output. The source levels used for determination of propagation loss are listed in Section 3.2 below.

(U) Finally the above values were edited for overload, inadequate signal-to-noise, and signal contamination. Range to each shot was determined by computing great circle distance from the hydrophone positions to the geographic positions supplied for each SUS. The propagation loss versus range plots for each hydrophone for each of 1/3 octave band center frequencies were then generated.

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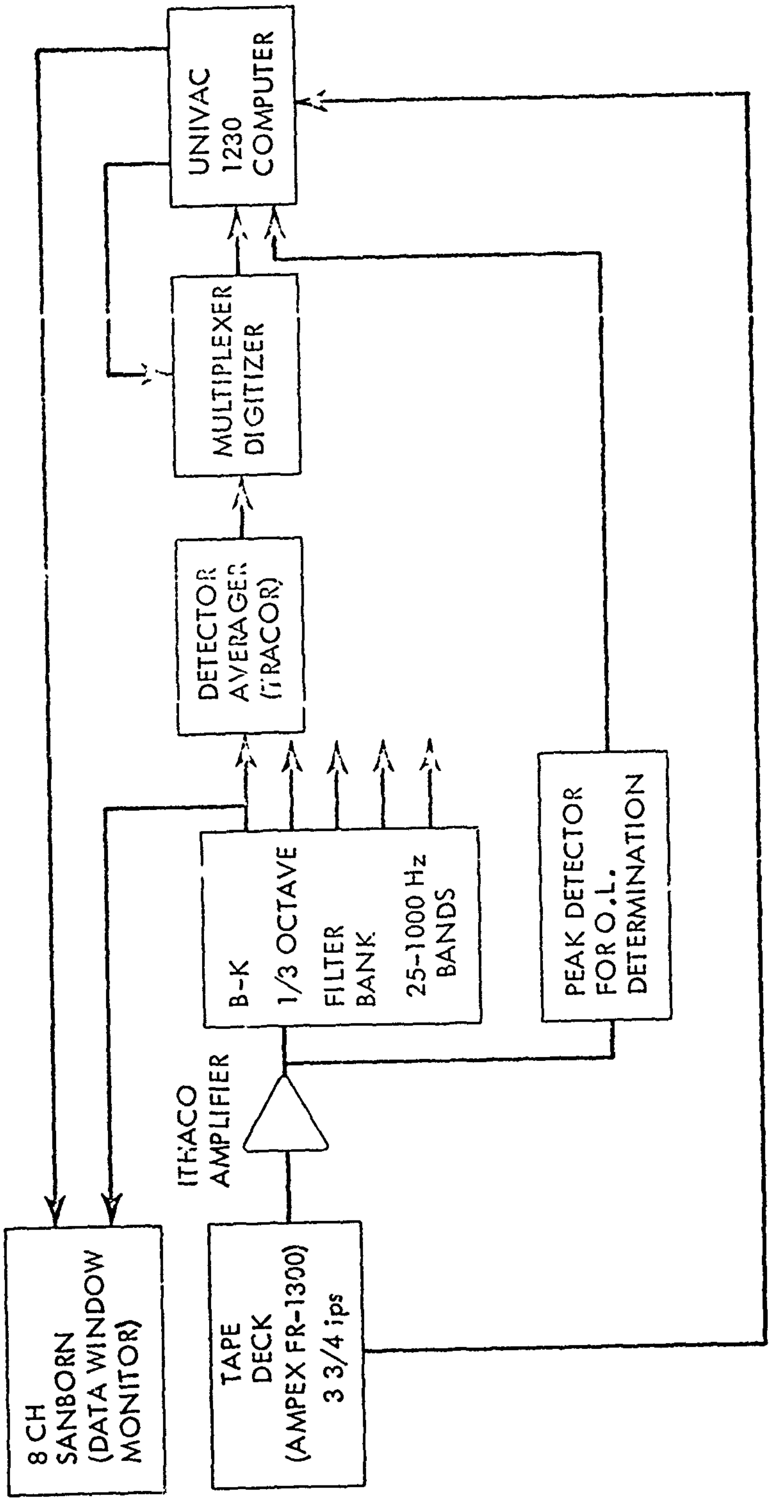

Figure 10

(U) SUS Data Processing Scheme

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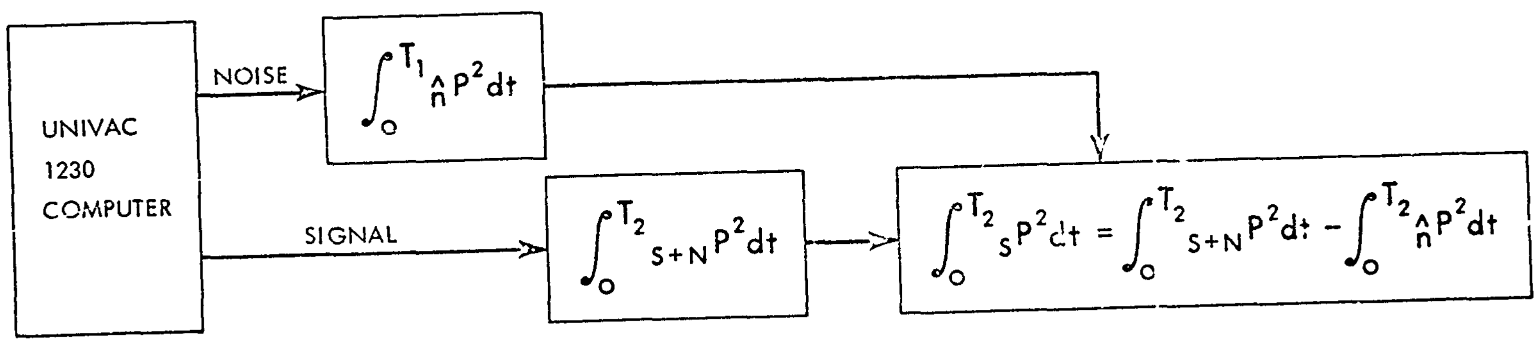


OUTPUTS INCLUDE

ENERGY PROPAGATION LOSS
NOISE SPECTRUM LEVEL - BANDWIDTH CORRECTED
S/N RATIO
PEAK PROPAGATION LOSS
INTEGRATION TIME
RECEIVED BAND LEVEL

(U) SUS Propagation Loss Calculations

Figure 11

3. Data

3.1 General

(U) The data set of this exercise is identified and partitioned in accordance with the following matrix:

	System	R'cvr. Locations	Sources						
			Ship		Aircraft				Vehicle
			NS1	NS2	A1	A2	A3	A4	Run No.
			E-B	C-D	A-C	C-D	D-C	C-E	Endpoints
Receivers	ACODAC	B	A,I	B,J					
	ACODAC	D	C,K	D,L					
	TABS	C			E	F	G	H	
	SONOBUOY	C			E	F	G	H	

(Note: Letters in boxes indicate data location appendix)

Table IV

(U) DATA PARTITION MATRIX

There are no data for the blocks crossed out. ACODAC data were reduced by two orgainizations, Woods Hole and the Applied Research Laboratory of the University of Texas (UT/ARL). The Woods Hole data were reduced by two methods as described in Sections 2.1.1 and 2.1.2 above and UT/ARL data reduction method is described in Section 2.1.3 above. TABS and SONOBUOY data were reduced by the New London Laboratory of the Naval Underwater Systems Center (NUSC/NLL); see Section 2.2 above. In all cases transmission loss was calculated and plots of transmission loss differences between hydrophones. Finally, from these pair difference curves relative transmission loss profiles were produced.

(C) Of the ACODAC data only the 50 Hz 1/3 octave band has been plotted, since this was the only band reduced by the WHOI hand method. Other principal 1/3 octave bands were reduced by the WHOI automatic and the UT/ARL methods. TABS and SONOBUOY data were plotted for the 25, 50, 100, 160, 200, 400 and 800 Hz 1/3 octave bands.

3.2 Source Levels

(U) In accordance with the instructions contained in Manager, LRAPP memorandum 102-OSC:RDG:bsj of 19 December 1973 source levels used were those of Gaspin & Shuler, reference 6. When converted to an effective source level at 1 yard and expressed as db re erg/cm^2/Hz in 1/3 octave bands, Gaspin & Shuler's results are:

1/3 Octave Band Center Frequency (Hz)	Depth of Source 18.3 M	Depth of Source 91.4 M
25	60.0	60.7
50	54.9	55.7
100	53.7	53.3
160	50.3	51.5
250	48.6	49.1

Table V

(U) SOURCE LEVELS

3.3 Evaluation

3.3.1 General

(U) To evaluate the data the following questions were addressed:

A. How do the data compare internally, i.e. against themselves? For example, how do the products of two data reduction methods, UT/ARL and WHOI, compare when operating on the identical raw data from the same hydrophone?

B. How do the data compare externally, i.e. against data from other sources? For example, how do TABS data compare against ACODAC data, even though measuring different runs?

C. How do the data compare with the predictions of theory?

In spite of the diversity of measurement and data processing systems the data appear to be mutually consistent. The long reverberation time and high reverberation energy associated with the trough structure complicated the measurement and analysis process.

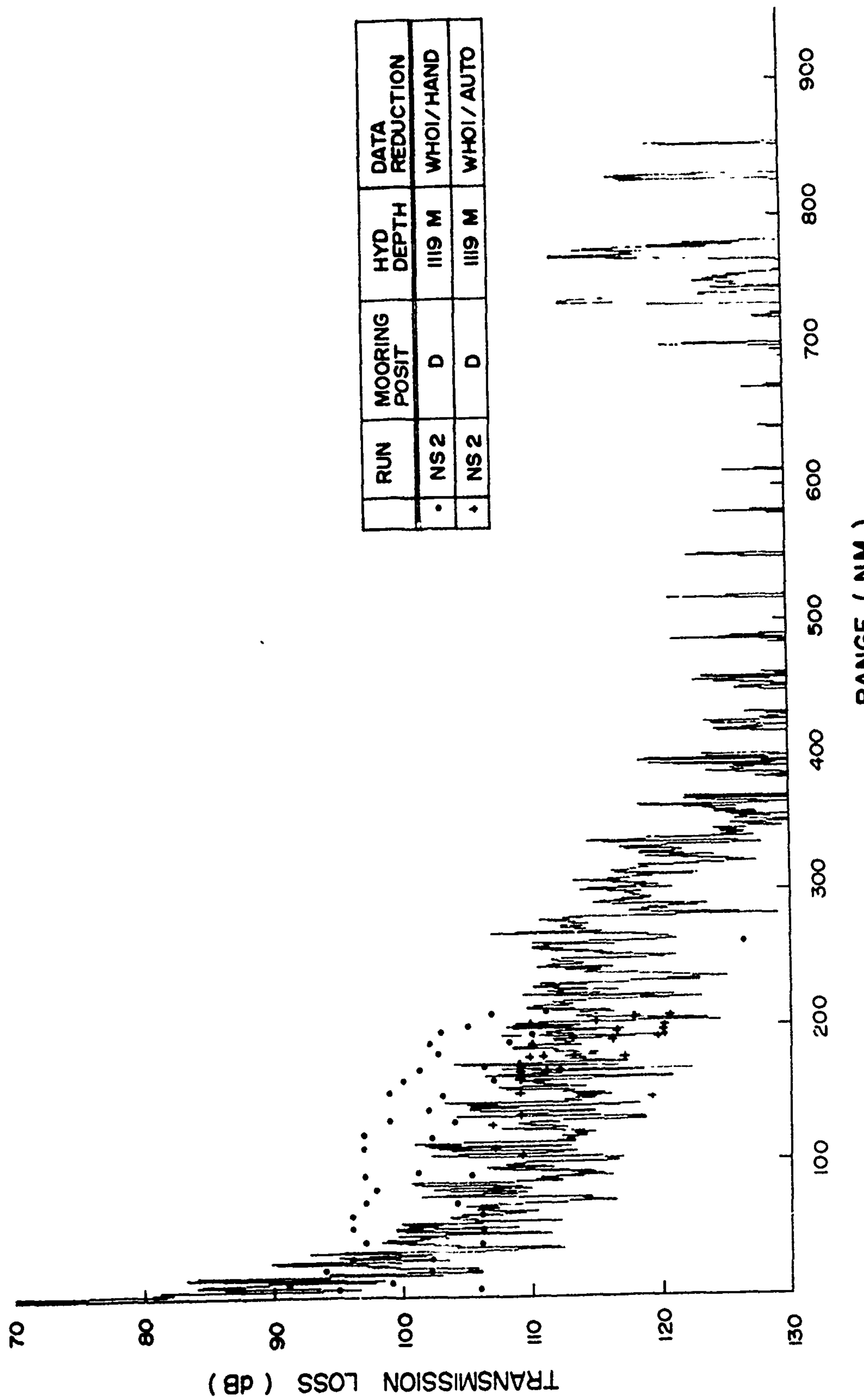
3.3.2 ACODAC Data

(U) Figures 12 through 17 compare experimental data against the predictions of theory. Three theoretical transmission loss curves were used as references: (1) a curve computed by the Fleet Numerical Weather Central (FNWC) and reproduced as Figure 2-108 of Reference 7, (2) a curve produced by an incoherent summation in a normal mode solution by the University of Texas, Applied Research Laboratory (UT/ARL), Reference 9 and (3) a curve produced by a coherent summation in a normal mode solution by UT/ARL, Reference 9. The FNWC's curve was based on an acoustic path along the axis of the Cayman Trough tending generally ENE from a position about 57 miles west of Posit D, a source and receiver depth combination of 120/900 meters was used at a 50 Hz 1/3 octave frequency. UT/ARL's curves were based on the precise acoustic path from Posits E to A to B to C to D using the bathymetry and sound velocity structure measured during the exercise and reported in Reference 5. The FNWC curves are compared against WHOI and UT/ARL measured values in Figures 12 and 13 respectively. The UT/ARL incoherent sum curves are compared against measured values in Figures 14 and 15, and the coherent sum curves, in Figures 16 and 17. The incoherent sum curve, although not "realistic" for open ocean propagation is included because none of the theoretical curves adequately take into consideration the effects of the boundaries of the Trough on the propagation. These boundaries will affect the interaction of the modes. Without further analysis it is impossible to predict the precise effects of the modification caused by boundary interaction. However, it is reasonable to anticipate that on the average the boundaries will increase the randomness of the phases and that the "true" transmission loss would fall somewhere between the incoherent and the coherent sum.

The following observations are made:

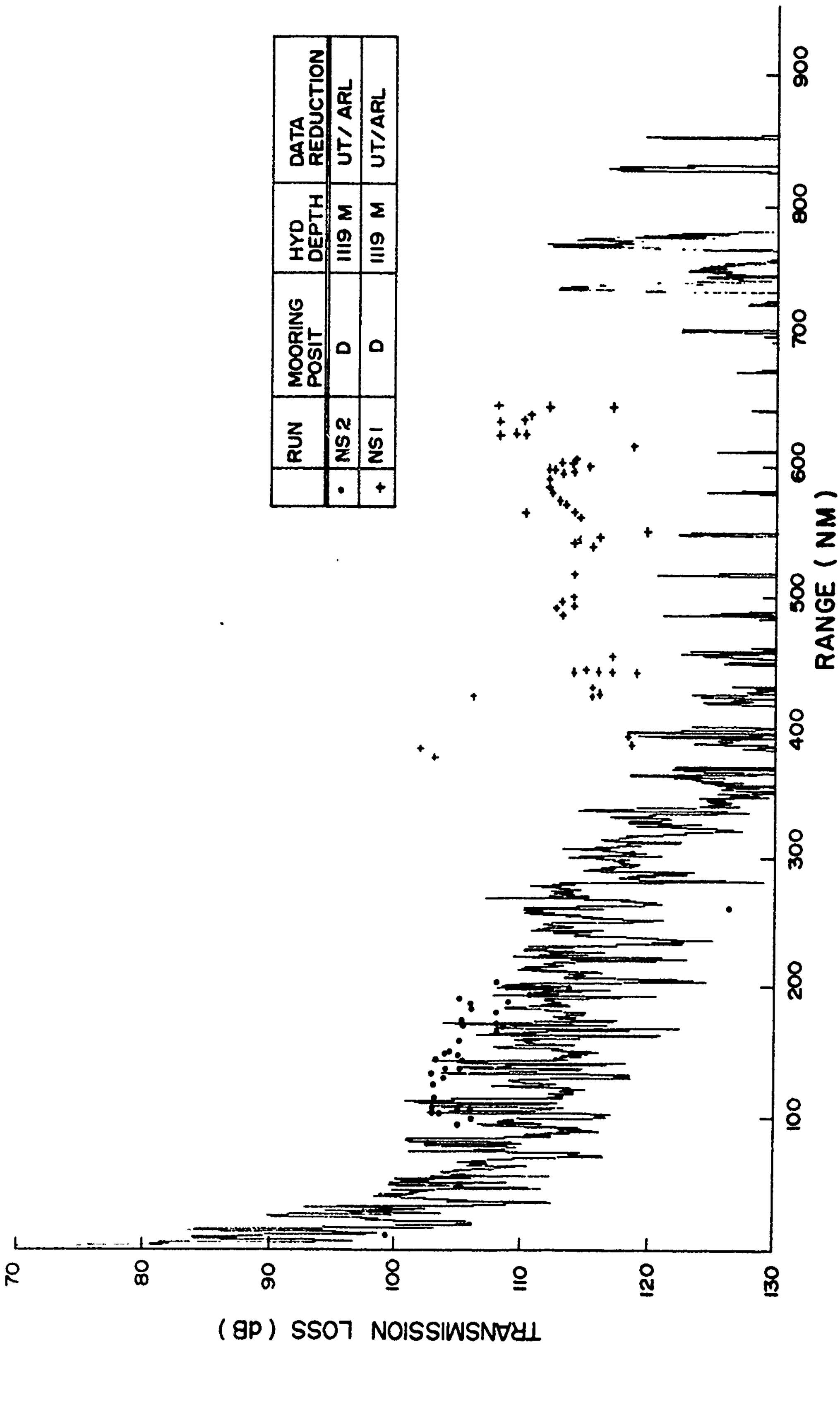
(U) A. The WHOI/HAND data are generally higher (less transmission loss) by up to 10 db than either the WHOI/AUTO or the UT/ARL data. Furthermore, as can be seen in Appendix D (pages D1 - D3), the WHOI/HAND transmission loss curve shows a band about 10 db wide at ranges less than 100 miles. The band narrows at ranges above 100 miles. These results suggest that the upper envelope of the WHOI/HAND curve is in error. SUS charges were dropped in pairs one minute apart. The first charge of the pair was intended as a "setting" charge; that is, it was intended to drive the ACODAC internal signal processing system into the next lower gain state (Reference 3) which was 10 db less sensitive. The WHOI/HAND data indicate that both pairs of SUS were analyzed and that the gain, "G", used in the equation (Sect. 2.1.1, page 11) was not changed between shots of the pair and hence not correct for one of them. The fact that the lower envelope corresponds more closely to WHOI/AUTO and UT/ARL data suggests that the gain state for the first of the pair was in error. The question arises in view of this uncertainty as to the value of the retention and reporting of the WHOI/HAND data. Two reasons prompt their inclusion: first, in the short ranges at Posit D for run NS 2 the data density for the other methods is very low and second, the WHOI/HAND data were very useful in the inter-hydrophone transmission loss difference studies (Sect. 4.3 and Appendix L, pages L1 - L8). The reason for the increased density of short range data for the WHOI/HAND method was the less stringent acceptance criterion employed by that method as compared to the automatic methods. In the WHOI/HAND method, the operator would decide which data to reject and which to accept; apparently his judgment was able to accept data which were momentarily or partially overloaded and hence rejected by the automatic methods.

(U) B. The WHOI/AUTO and UT/ARL data are closer to the coherent theoretical curves (FNWC), Figures 12 and 13, and UT/ARL, Figures 16 and 17) than are the WHOI/HAND data.



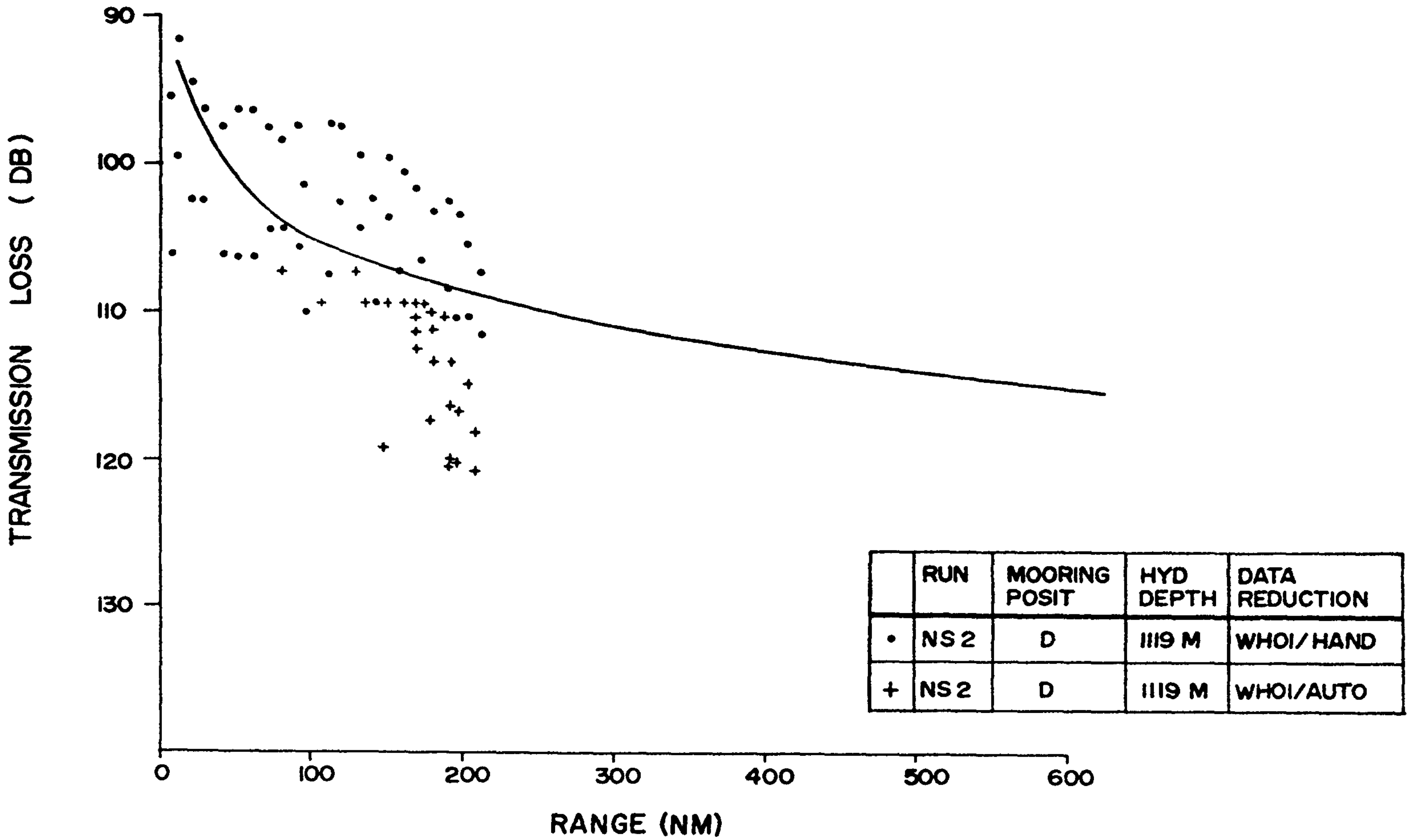
(C) Transmission Loss Comparisons
WHOI Data to FNWC Curve

Figure 12



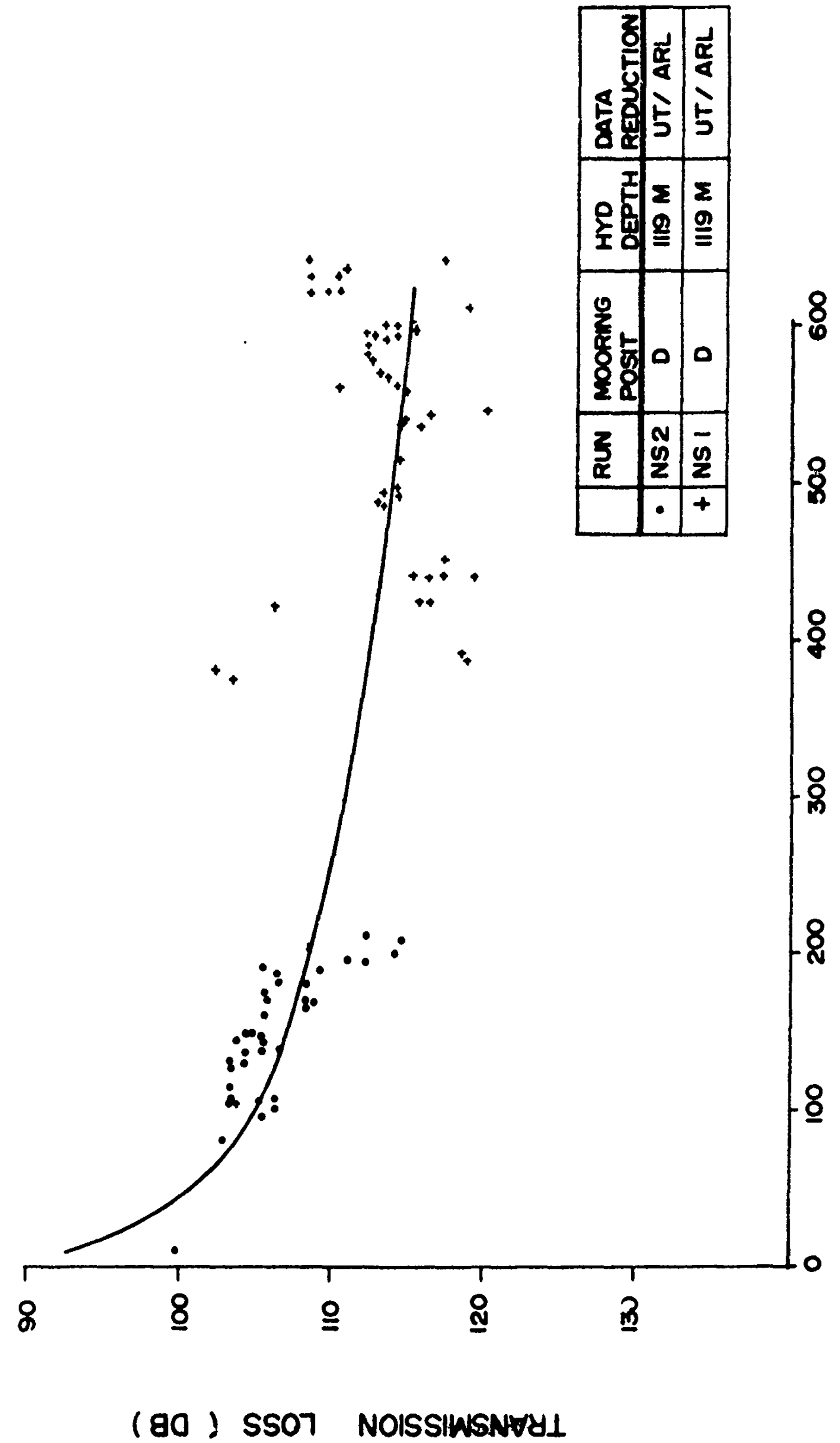
(C) Transmission Loss Comparisons
UT/ARL Data to FNWC Curve

Figure 13



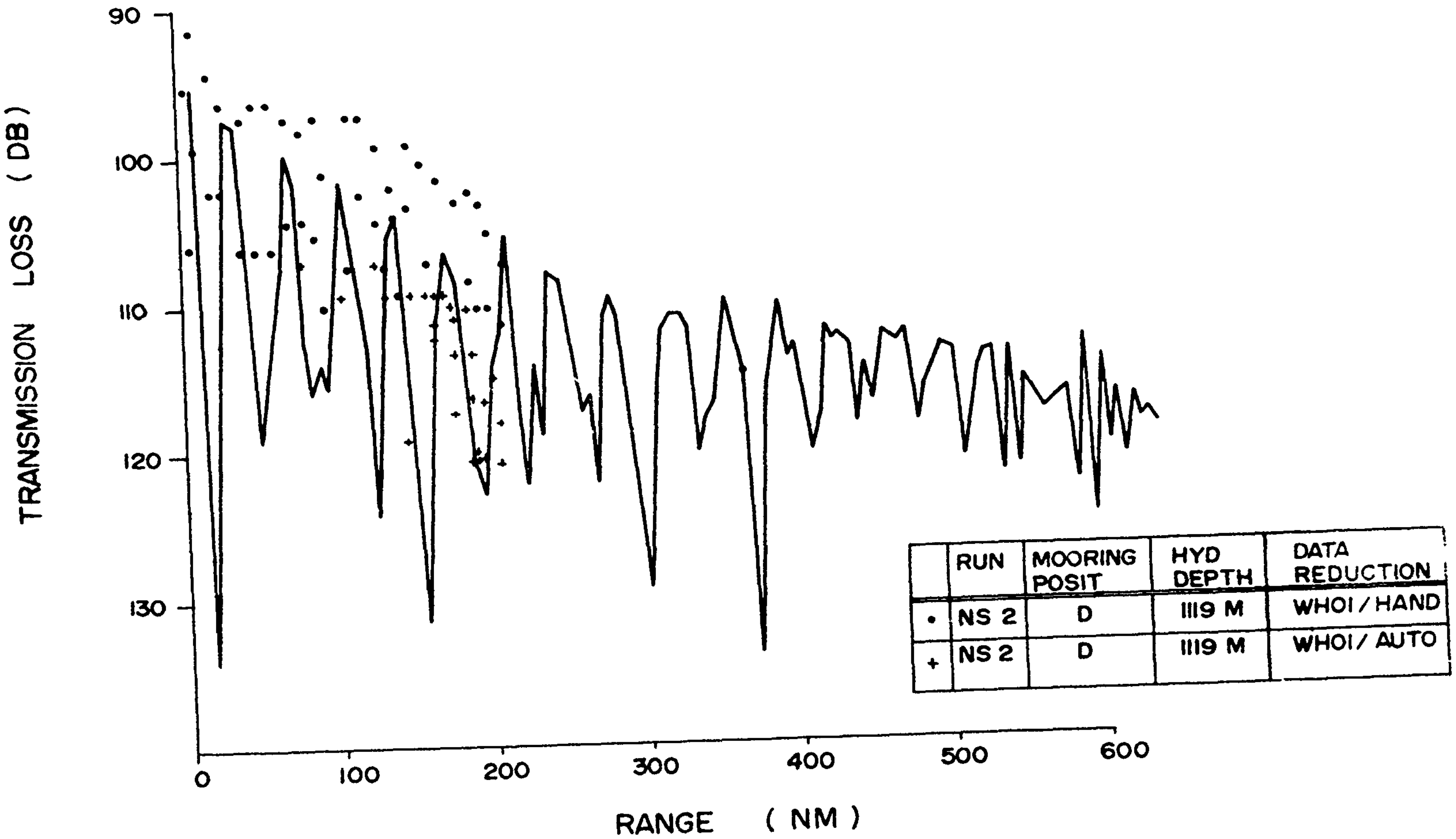
(C) Transmission Loss Comparisons WHOI Data to UT/ARL Incoherent Sum Curve

Figure 14



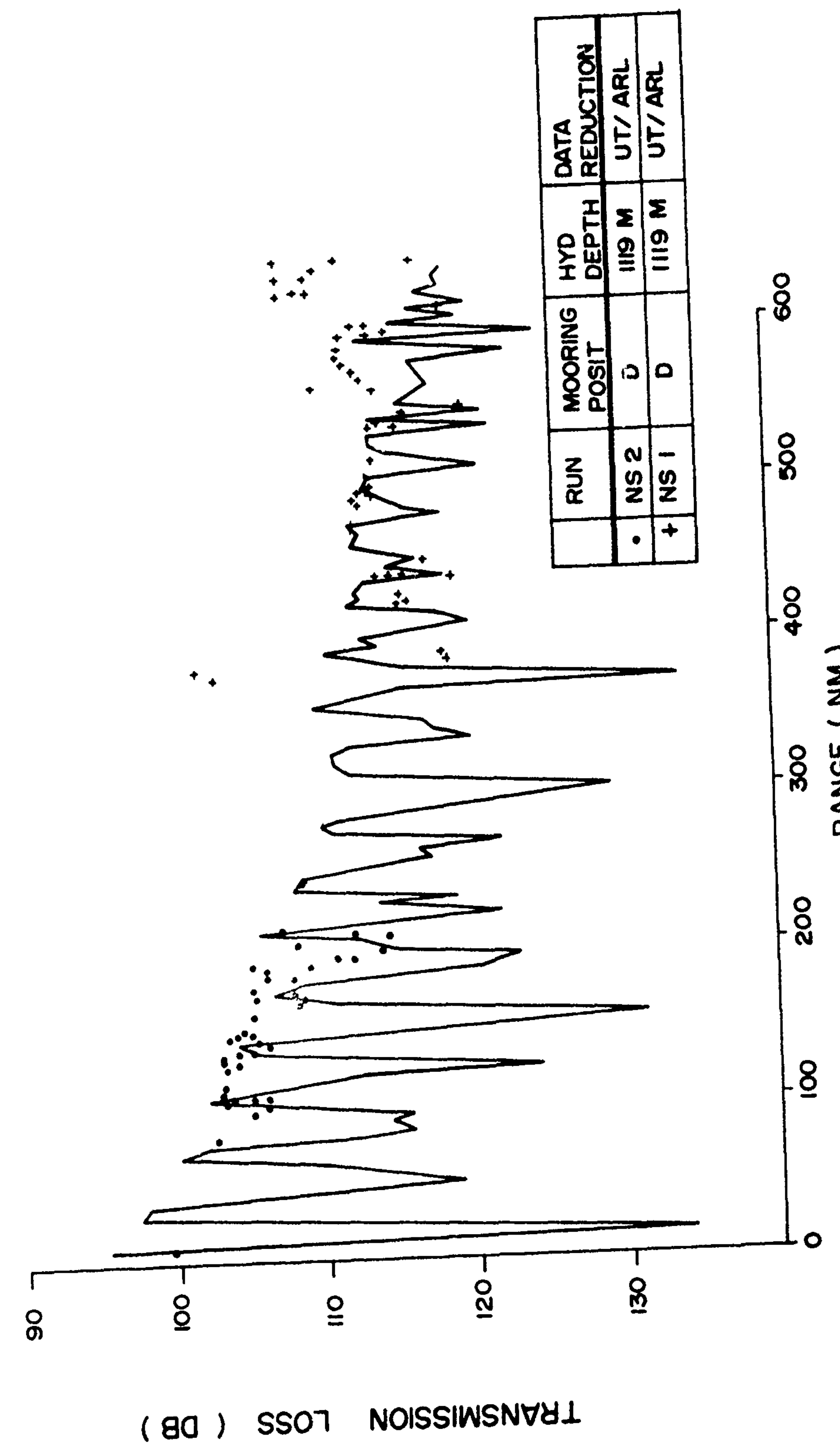
(C) Transmission Loss Comparisons UT/ARL Data to UT/ARL Incoherent Sum Curve

Figure 15



(C) Transmission Loss Comparisons WHOI Data to UT/ARL Coherent Sum Curve

Figure 16



(C) Transmission Loss Comparisons UT/ARL Data to UT/ARL Coherent Sum Curve

Figure 17

(U) C. The UT/ARL incoherent sum theoretical curve more or less "splits the difference" between WHOI/HAND and WHOI/AUTO data. The UT/ARL data are more closely grouped about this curve than are the WHOI data.

(U) D. For Run NS 2 the WHOI/AUTO data seem to fit the UT/ARL coherent sum theoretical curve, Figures 16 and 17 better than do the UT/ARL data which do not show deep interzonal depressions in the range interval from 80 to 160 miles.[1]

(U) E. For Run NS 1 the UT/ARL data are poorly fitted to the FNWC theoretical curve, Figure 13 in the range internal from 400 to 650 miles. The fit of these data to the UT/ARL coherent sum curve, Figure 17 is good from about 400 to 540 miles. There is some evidence of bathymetric focussing in the range interval 550 to 630 miles.

The overall evaluation of the data processing methods follow:

(U) A. For ranges out to 250 miles the WHOI/AUTO method provides data better fit to the FNWC and UT/ARL coherent sum theoretical curves than does the UT/ARL method.

(U) B. The WHOI/HAND method does not provide data with a good fit to any referenced theoretical transmission loss curve. While this fact alone does not invalidate the data, it casts suspicion on their validity for measures of absolute transmission loss, but not for relative transmission loss; i.e. differences in transmission loss between hydrophones.

(U) C. The good fit between the UT/ARL data and the UT/ARL coherent sum theoretical curve at ranges from 400 to 530 miles provides confidence in both the data processing method and the validity of the theoretical curve in this interval. Conversely the poor fit between the UT/ARL data and the FNWC theoretical curve casts doubt of the validity of the FNWC curve in this range interval.

3.3.3 TABS and SONOBUOY Data

(C) These data which are shown in Appendices E, F, G and H, appear to be internally consistent. When compared against themselves and against ACODAC data the following observations are noted:

(C) A. Transmission loss is an insensitive function of source depth between sources at 18.3 and 91.4 meters to a receiver at 91.4 meters.

(C) B. Transmission loss is a relatively sensitive function of receiver depth for both receivers in the channel above the axis. When data for the aircraft D-C run (source depth 91.4 meters) are compared for receivers at 91.4 and 244 meters, it is found that the signal at the deeper depth is some 3 to 10 db higher with the greatest differential found in the range interval 90 to 130 miles.

(C) C. Aircraft C-E run data for the 50 Hz 1/3 octave band compare favorably with UT/ARL and WHOI/HAND data as a function of range up to 200 miles. The decrease in transmission loss with range above 300 miles for the aircraft data is consistent with the ACODAC data above 450 miles if one takes into account that Posit C (measurement point for TABS and SONOBUOY data) is about 150 miles ENE of Posit D (ACODAC measurement point). This decrease of transmission loss is evidence of bathymetric focussing from sources near the NE end of the trough.

(C) D. By providing good coverage at close range (out to two convergence zones) where ACODAC data tend to be sparse, TABS and SONOBUOY data complement ACODAC data.

[1] The term "miles" used in this report is to be interpreted as "nautical miles".

4. Results and Significance

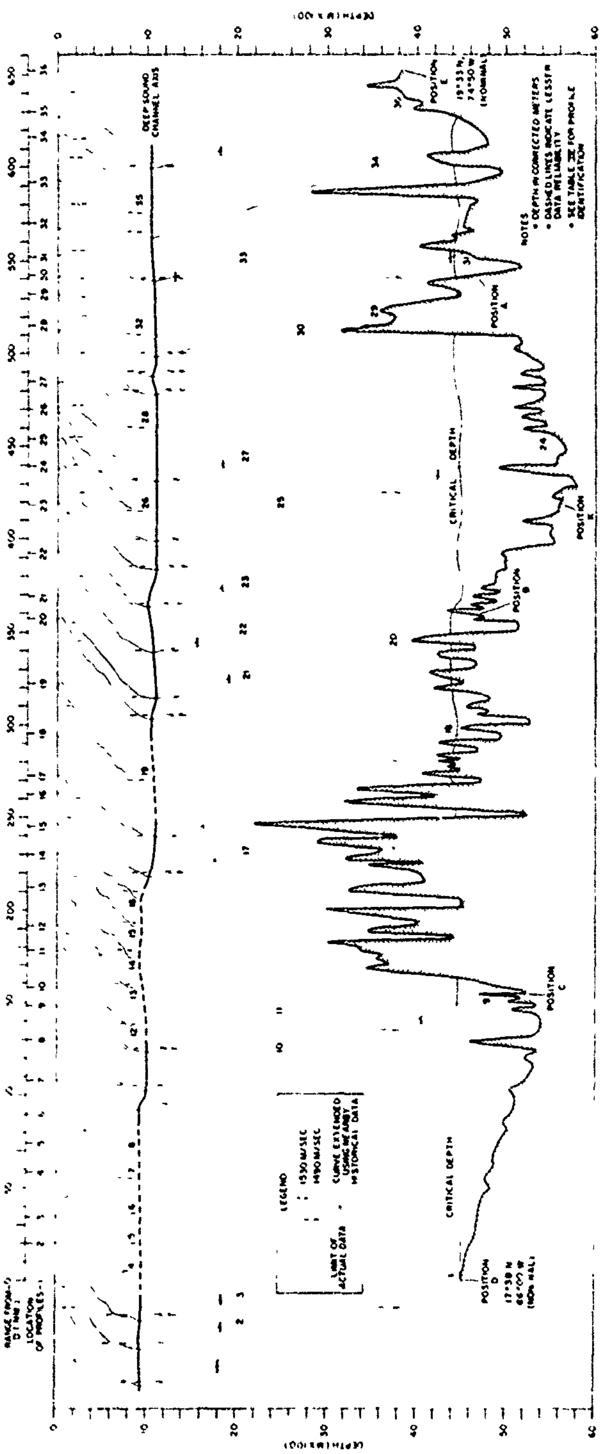
4.1 General

(C) The transmission loss results in the Cayman Trough showed the effects of peculiar geometry of that region. Strong evidence of bathymetric focussing, i.e. the coupling of acoustic energy into the sound channel from bottom reflections, is found in the longer range (i.e. greater than 450 mi.) portions of runs. At these ranges where the source was near Posit A, one sees an increase in signal (decrease in transmission loss) with increasing range. Another boundary effect in both reflection and scattering was the obliterating of the strong convergent zone structure seen in SOFAR propagation in the open ocean. That the convergence zones were functioning properly except for boundary contamination is shown in the sharply range dependent depth effect seen in the relative transmission loss.

4.2 Range Dependence

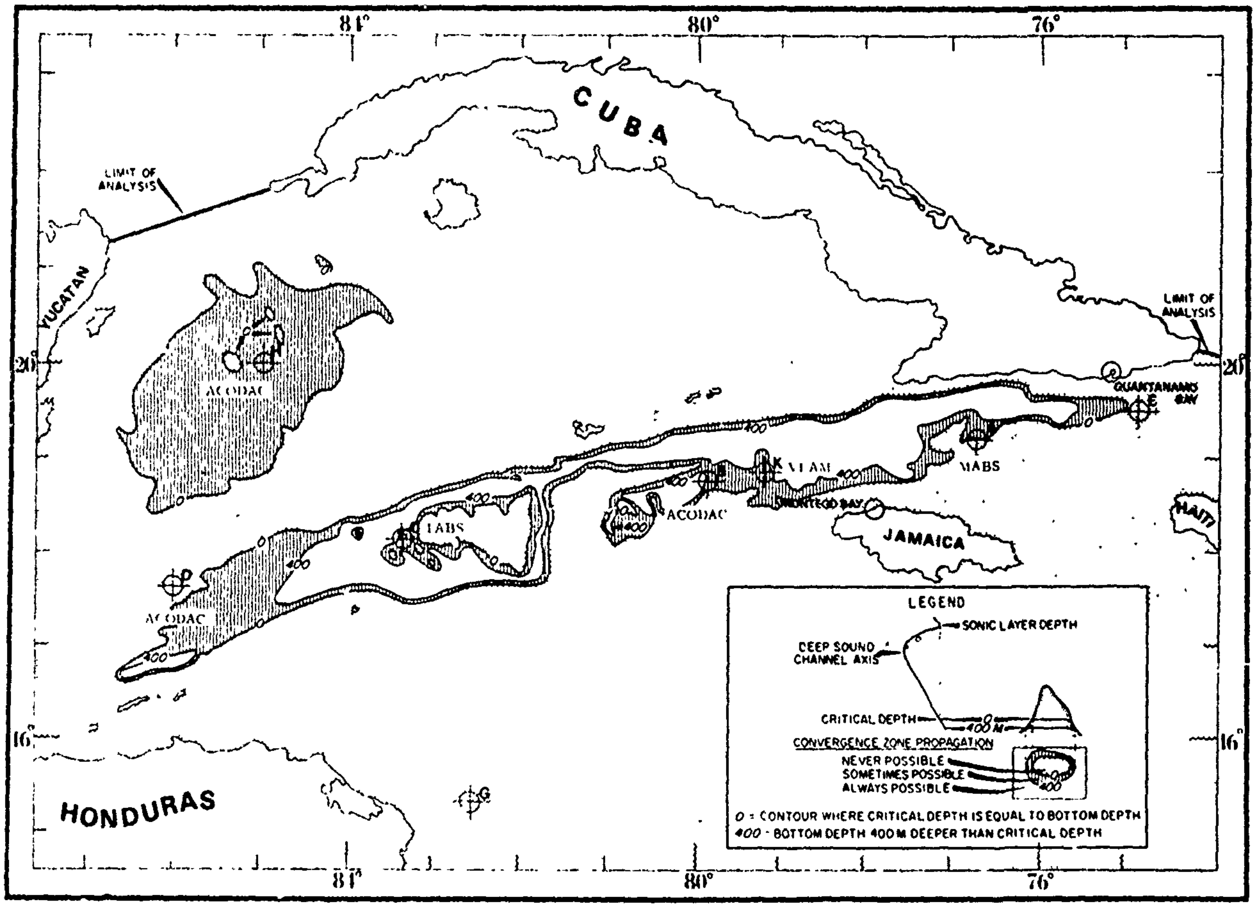
(C) An understanding of the complete mechanism of range dependence in an area as acoustically complex as the Cayman Trough must necessarily involve considerable effort at theoretical analysis which includes the effects of the boundaries of the Trough, both vertical and horizontal. Since this theoretical analysis was not done, our understanding of the mechanisms must be incomplete and include a degree of speculation. The area of the acoustic path to Posit D may be divided into three separate domains each with its dominating topographic influence. These are the close-in region extending out to 160 miles (D to C), the intermediate ridge region extending from 160 to 365 miles (C to B) and the far region beyond 365 miles (B to E). The effects of these regions may be understood by reference to Figures 17, 18 and 19. In the close-in region there is depth excess, but the Cayman Bank along the north side of the trough at a depth of 4000 meters extends 450 meters upward into the deep sound channel. The measured propagation loss tends to follow the upper envelope of the coherent sum range curve (Figure 17) to a range of about 160 miles; beyond this there is a marked increase in transmission loss. These effects suggest that energy reflected from the Cayman Bank "washes out" the transmission loss maxima between convergence zones. Beyond 160 miles the beginning of the acoustic path has negative depth excess, which can attenuate the transmitted energy. Unfortunately there are few data in the intermediate ridge region; SUS run NS 1 terminated at Posit B and SUS run NS 2 started only 60 miles from Posit C. The intermediate ridge structure protrudes to as far as 2200 meters into the deep sound channel. It exerts marked influence on signals emanating from the far region beyond Posit B. Near Posit B the topography produces two opposite effects: one is the severe attenuation of the signal by the baffling of the intermediate ridge and the second is an intensification due to a boundary reflection into the sound channel, i.e. bathymetric focussing. It is likely that the two readings which are some 8 to 10 db above the upper envelope (i.e. less transmission loss) of the curve of Figure 15 are produced by this latter mechanism. As the range increases beyond 400 miles the baffling effect of the intermediate ridge exerts less influence and the transmission loss actually decreases with increasing range. As the range extends well beyond Posit B into the far region, four possible mechanisms account for the decrease in transmission loss:

1. Diffraction through the intermediate ridge region,
2. Wave guide propagation through a narrow trench to the north of the intermediate ridge,



(U) Sound Velocity Profiles from Position D to Position E
(27 Nov - 13 Dec 1973)

Figure 18



(U) Exercise Area, Acoustic Measurement Devices and Interval Between Critical Depth and Ocean Floor

Figure 19

3. Bathymetric focussing from topographical features in the vicinity of the source, and

4. Spatial band pass filtering through the intermediate ridge.

Reference 9 suggests (1), (2) and (3) as possible causes of the anomalous transmission loss effects beyond 400 miles. Identifying the dominant mechanisms from among the possibilities on the basis of existing data does not appear feasible.

(C) 4.3 Depth Dependence

A combined effect of depth and range was found in the transmission loss curves. At certain ranges the energy of signals received at different depths differed markedly; at other ranges there was little differences as a function of depth. This effect is best illustrated by plotting the differences in signal energy between hydrophones. This has been done in Appendices I, J, K and L where transmission loss difference between hydrophone pairs is plotted versus range. A fine structure of sharply defined differences of the order of 5 to 10 db and of mile wide range increments appears in a regular pattern which is keyed to the convergence zone structure. These bands of sharp depth effect generally occur near and on the far side of convergence zones. During these periods of large depth effect the deep hydrophones usually show a larger signal than the shallow hydrophones. Relative profiles based on the pair differences of Appendices I, J, K and L, are shown in Figures 20 through 29 . In general, when the large depth effect occurs, the hydrophones near the bottom of the sound channel will receive a stronger signal than hydrophones near the axis. This effect is most probably a manifestation of conjugate focussing of energy from a shallow source within the deep sound channel; in this case the source was at 91.4 meters.

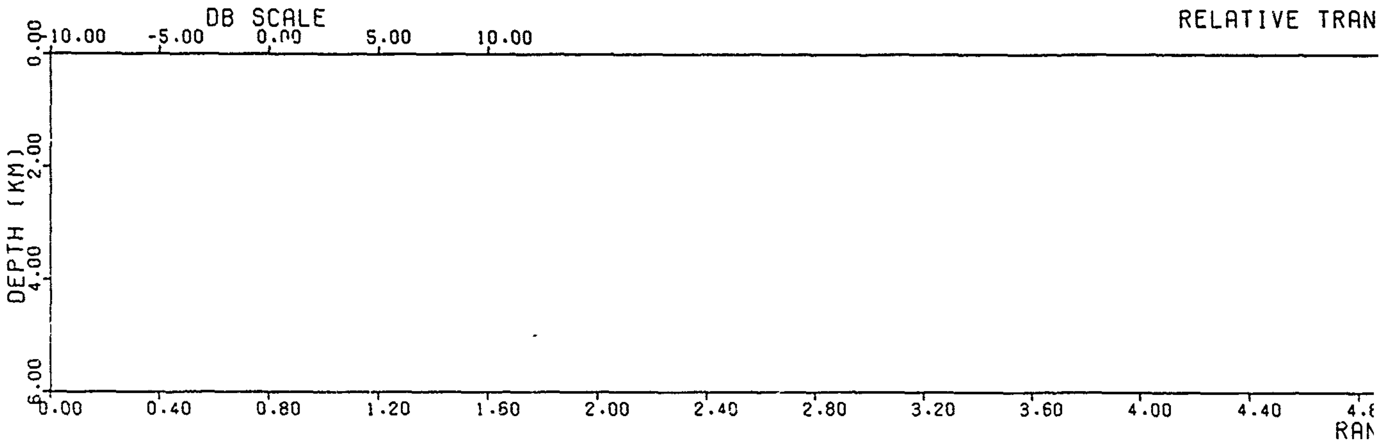
(C) 4.4 Signal to Noise Implications

The results of the transmission loss study must be combined with the results of the ambient noise investigation, Reference 4, in order to derive implication on the placement of ASW surveillance systems. If there were complete freedom in geographical placement (in the northwest Caribbean) and in depth of sensors, the following conclusions may be drawn:

A. The vicinity of Point D would be a good choice for the location of a surveillance system with primary beam looking ENE along the strike of the Cayman Trough.

B. If only one monitoring depth were to be allowed, surveillance hydrophones should be placed near the critical depth for best performance over a long period of time.

C. The lateral range curve would show discontinuities due to conjugate focussing effect discussed above and it would vary with time due to ambient noise fluctuations discussed in Reference 4.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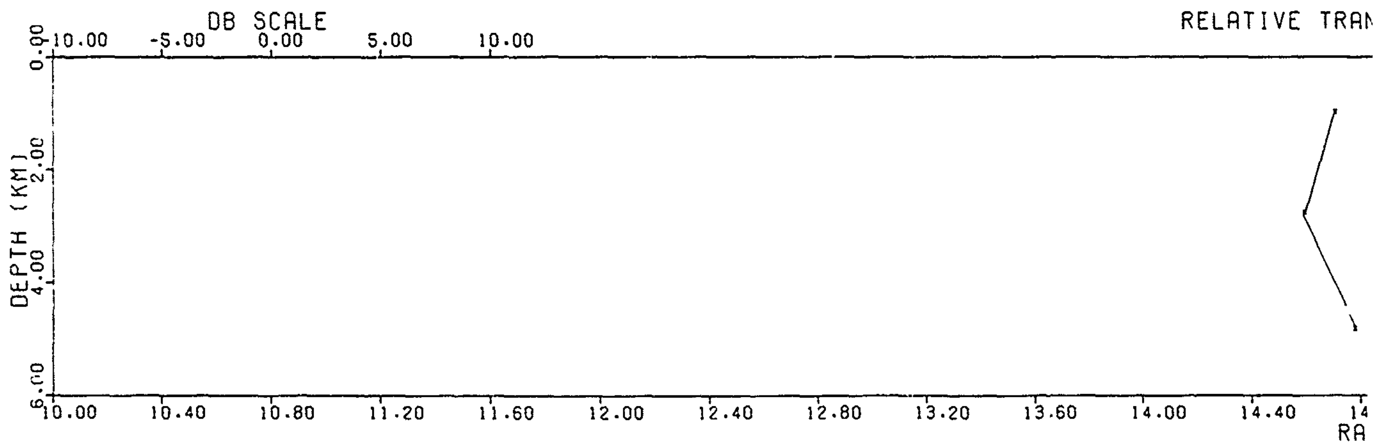
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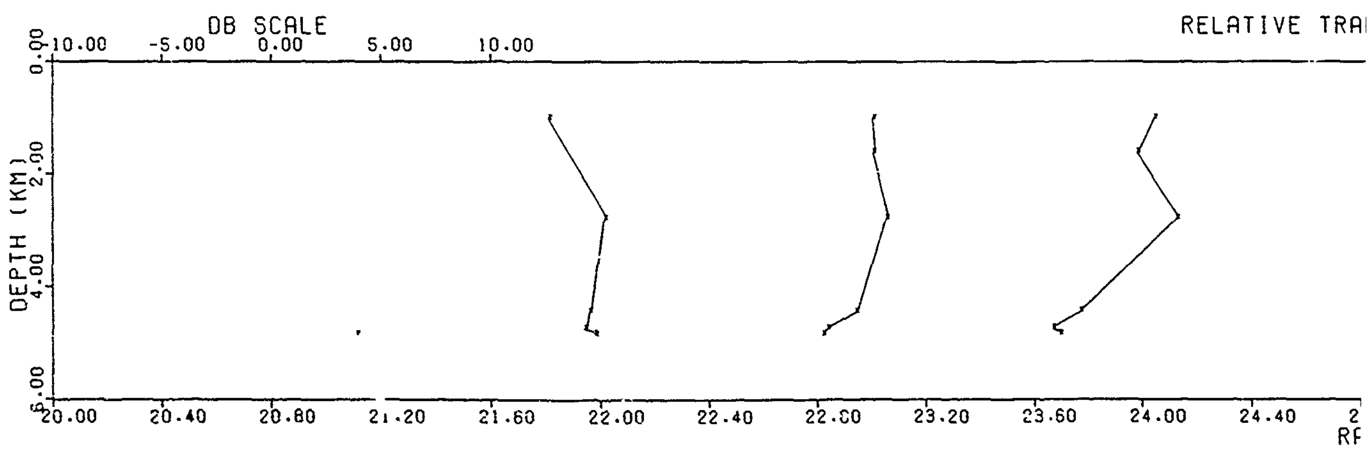
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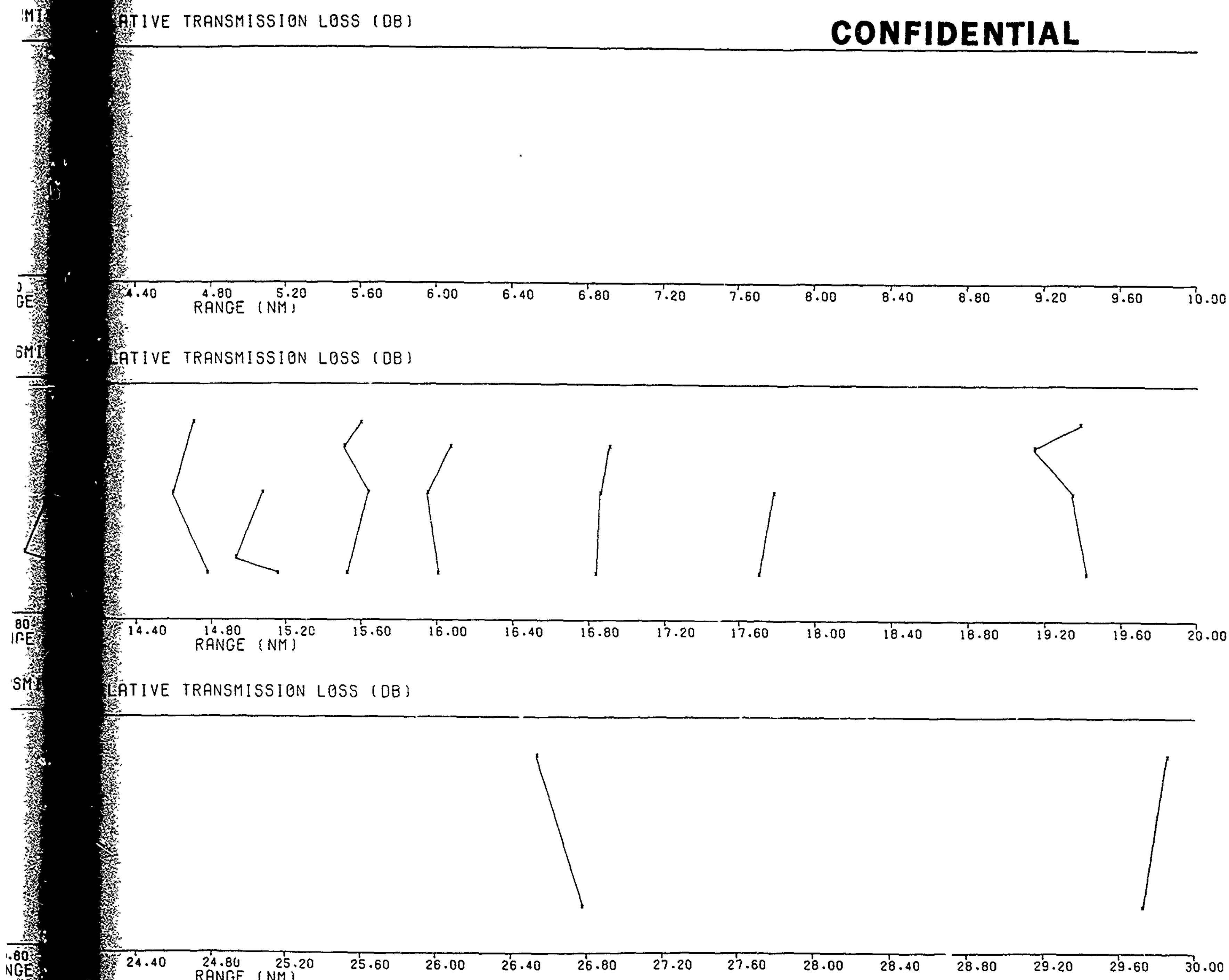
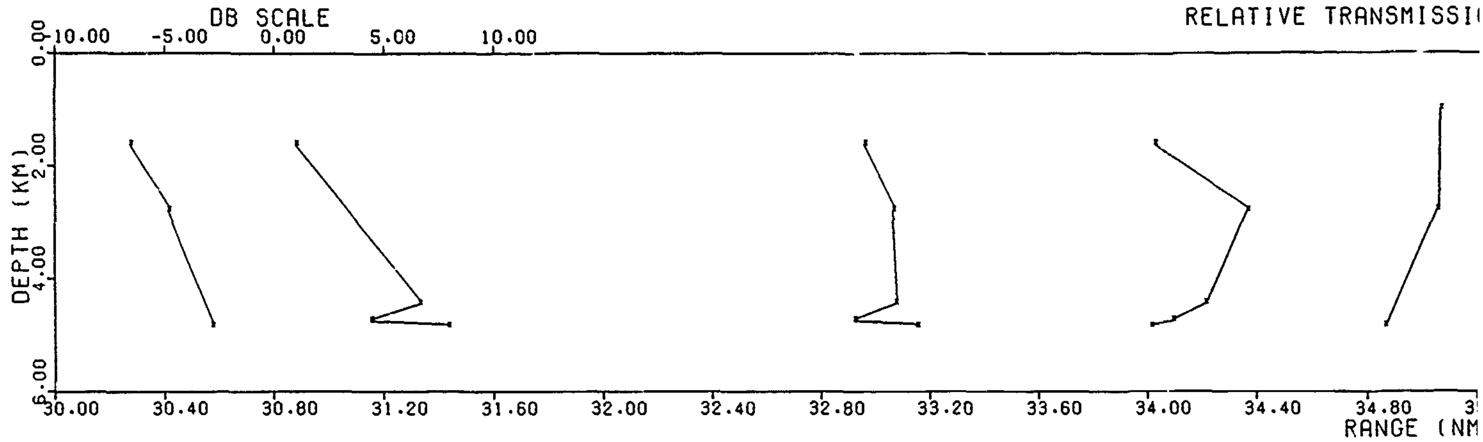
24.00
24.40



(C) Relative Transmission Loss Depth Profiles at Posit B, 0-30 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 20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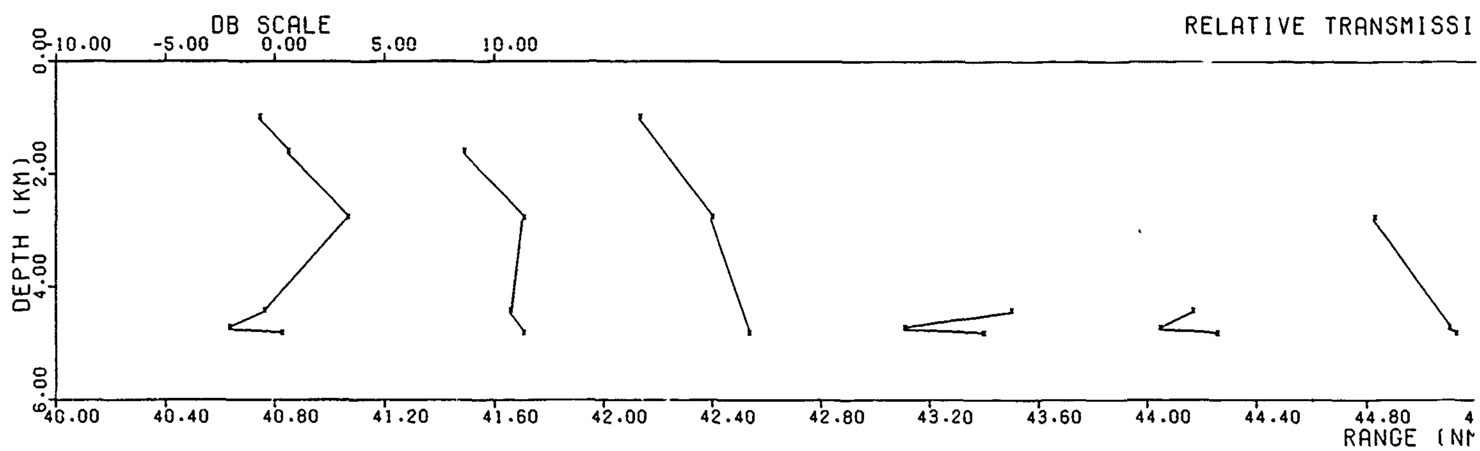
RANGE (NM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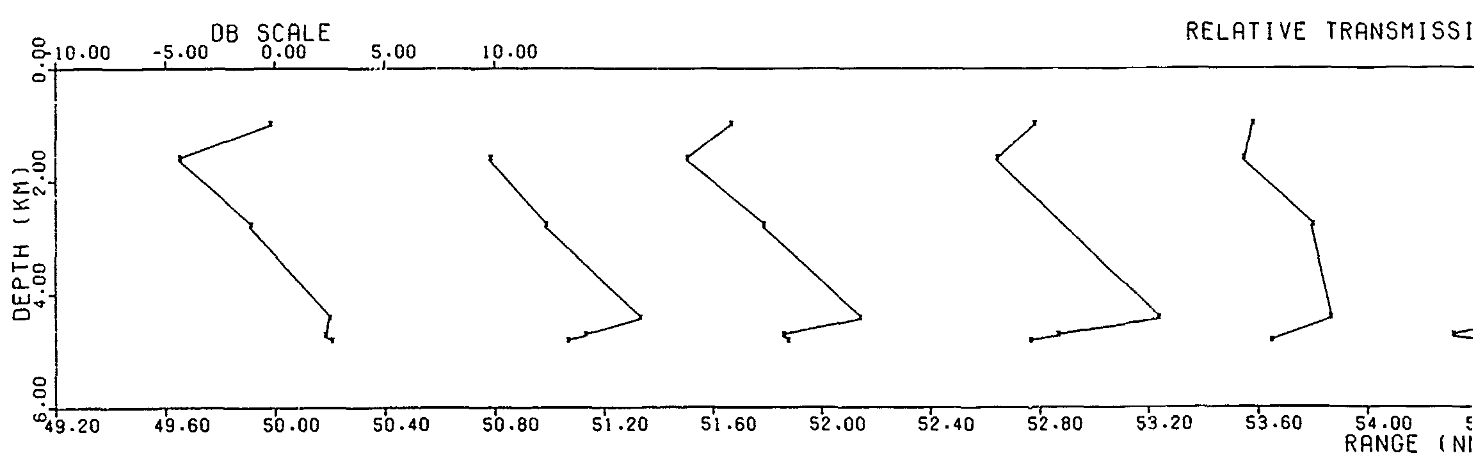
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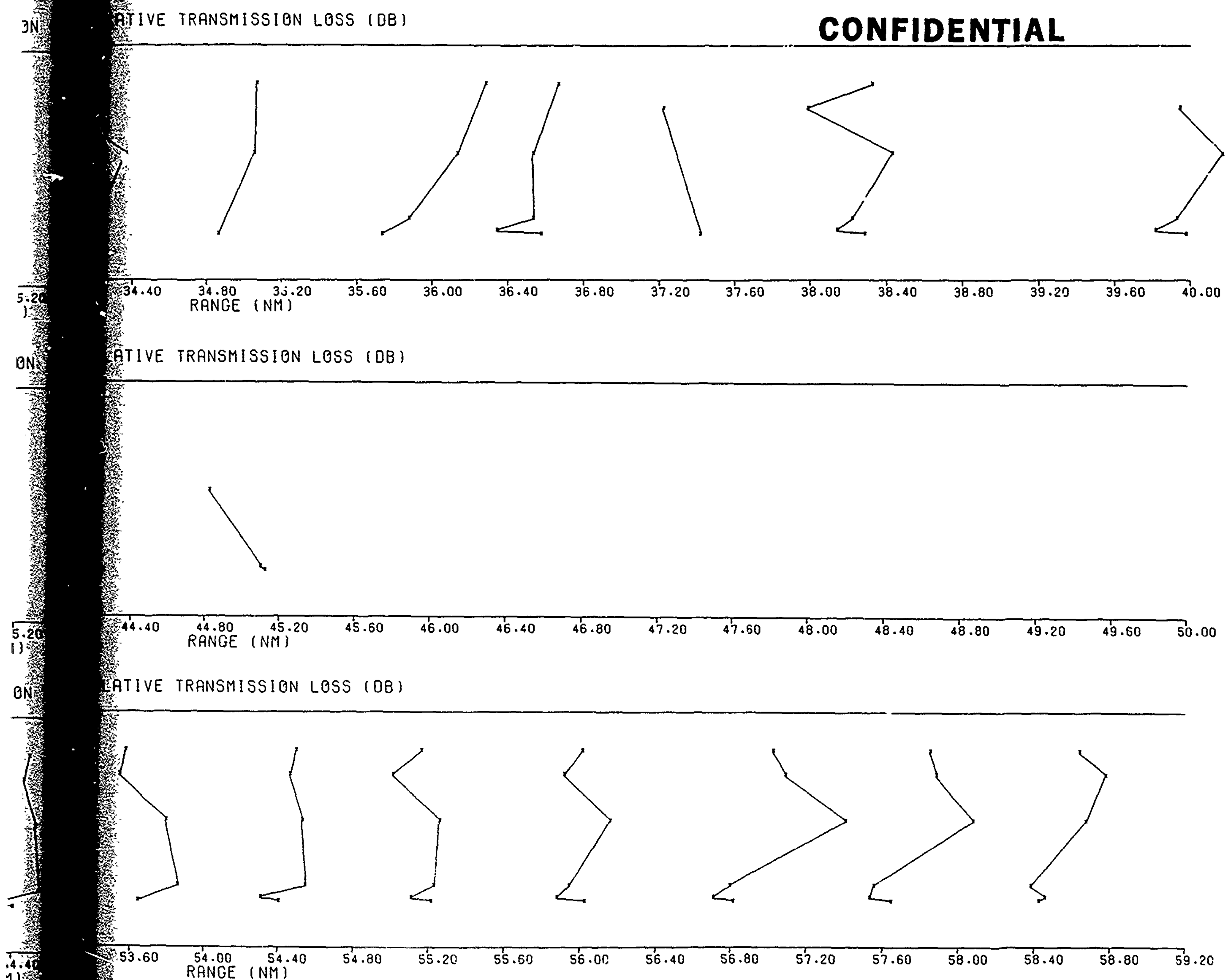
RANGE (NM

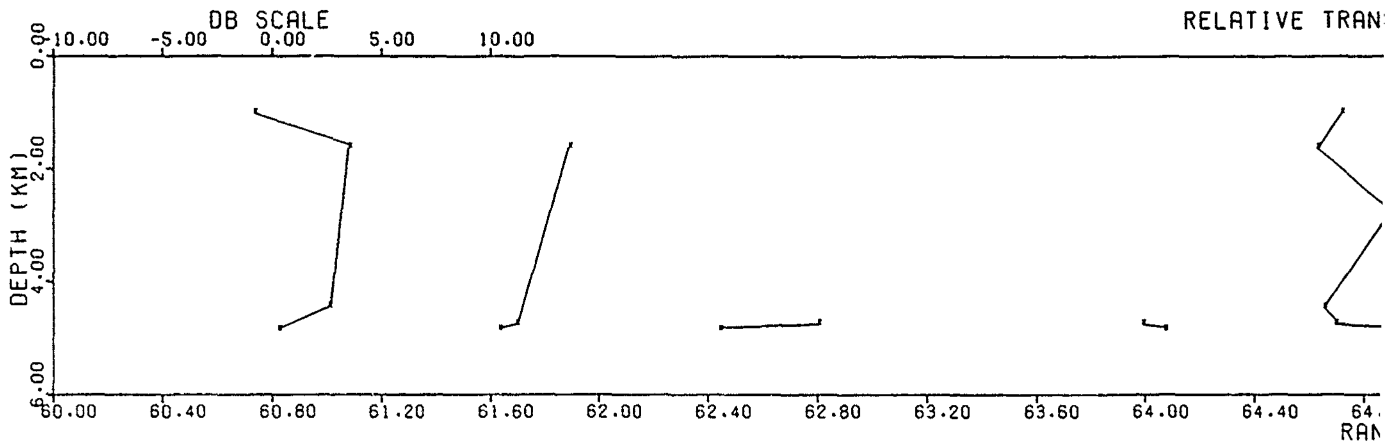
CONFIDENTIAL



(C) Relative Transmission Loss Depth Profiles at Posit B, 30-60 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 21

CONFIDENTIAL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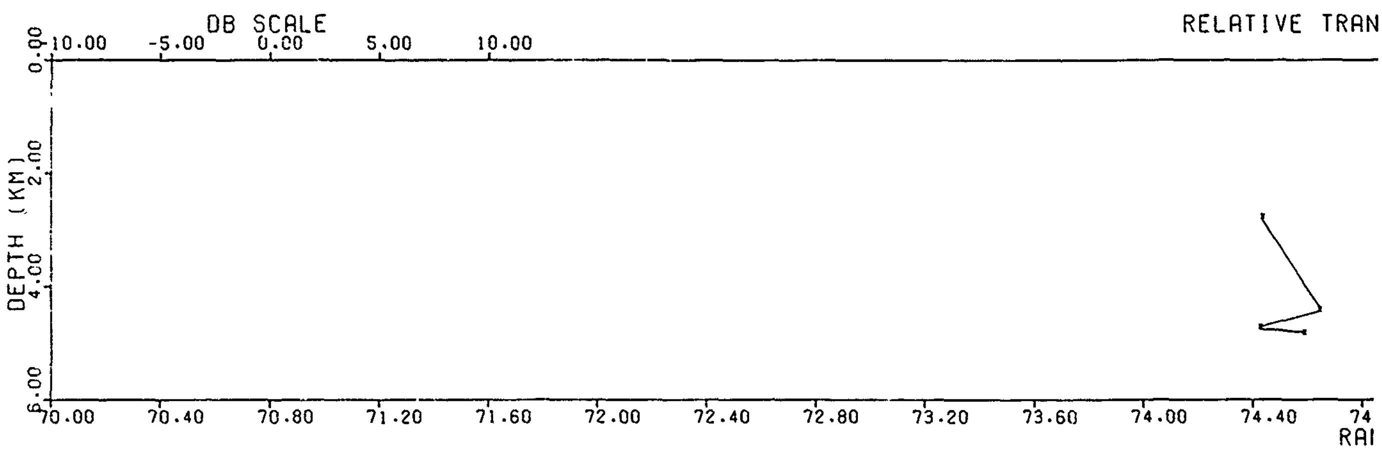
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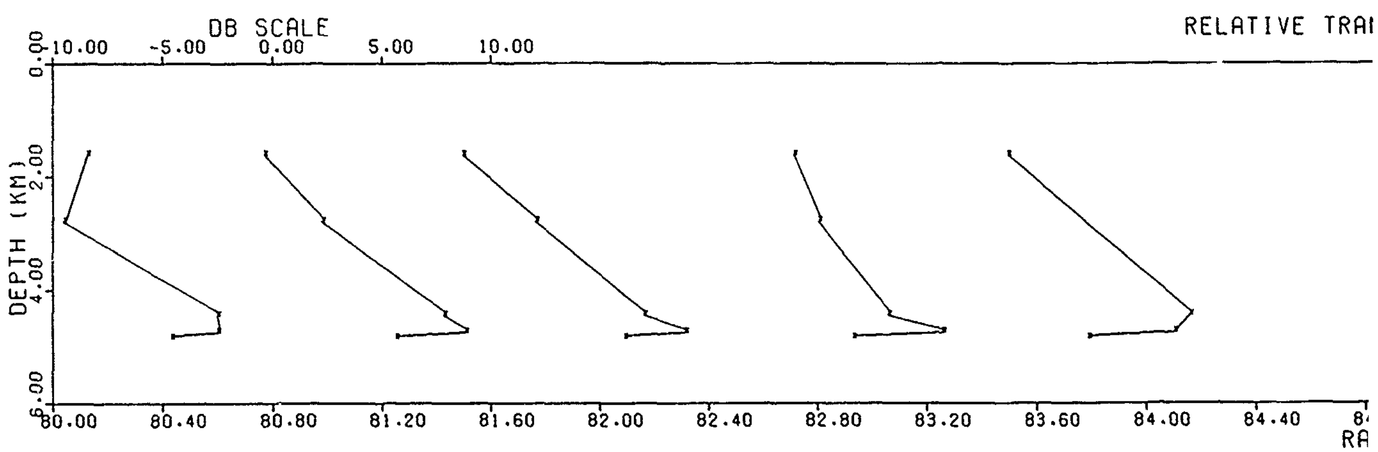
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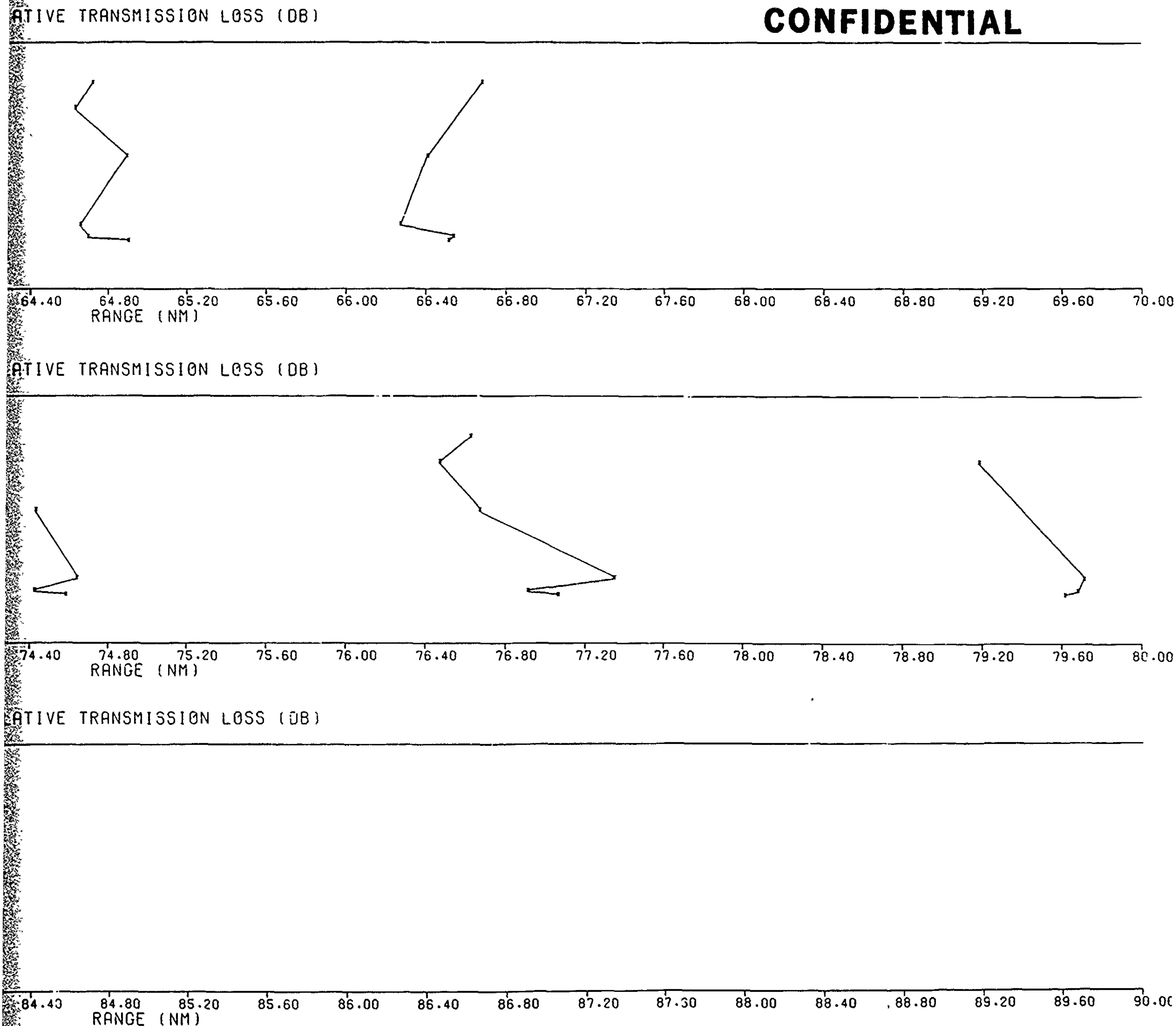
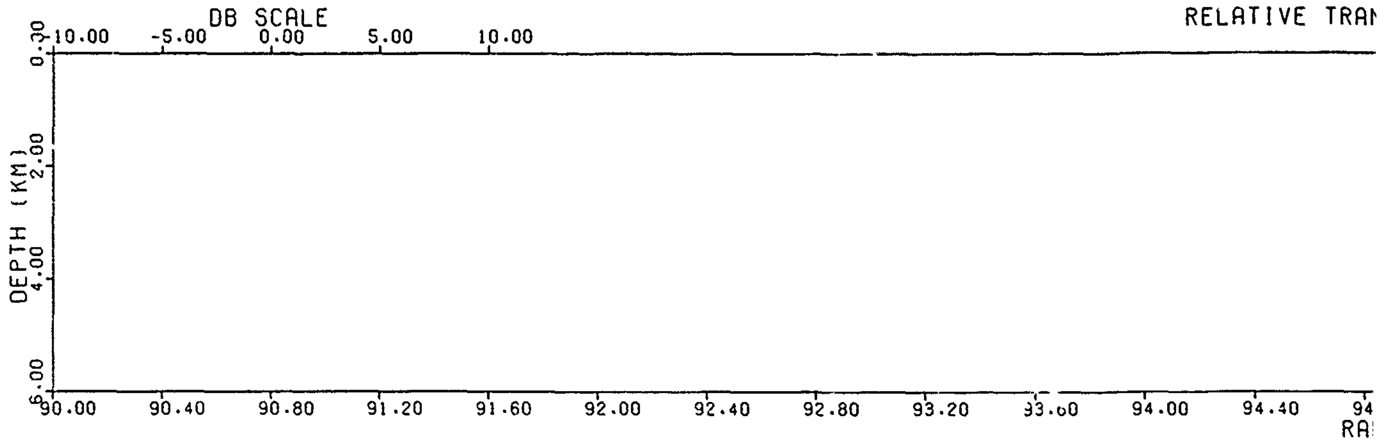


(C) Relative Transmission Loss Depth Profiles at Posit B, 60-90 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 22

2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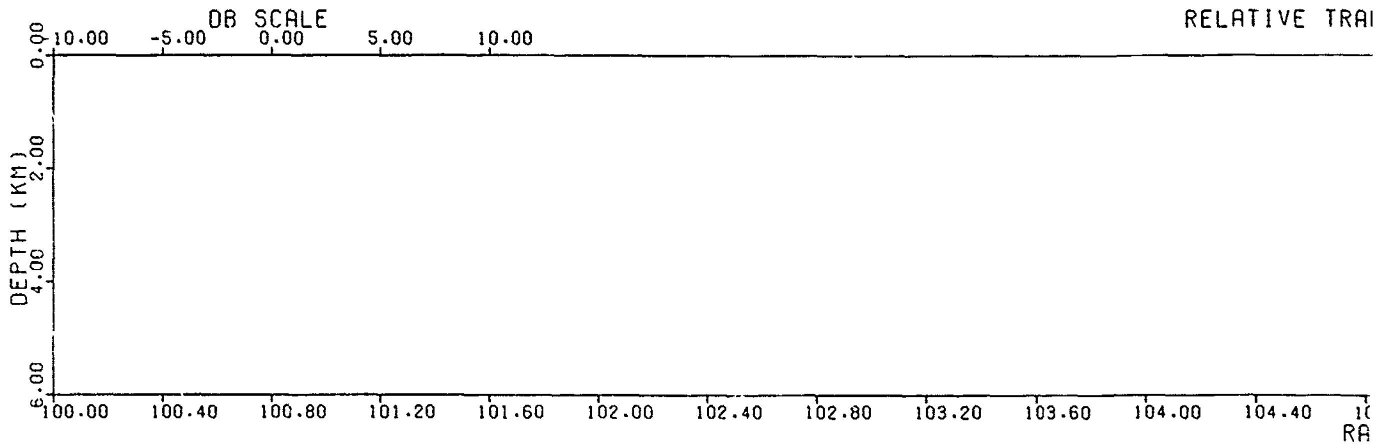
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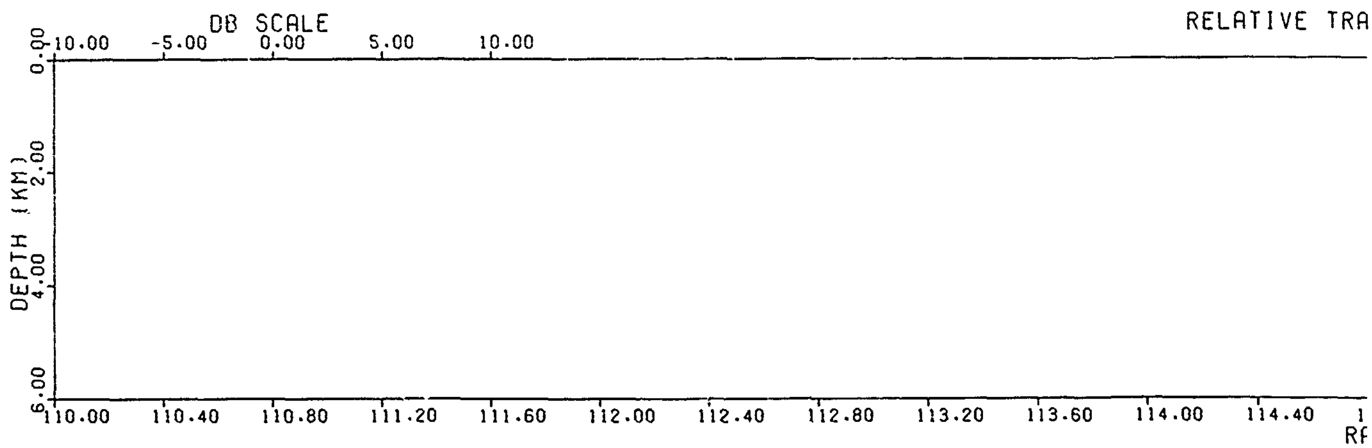
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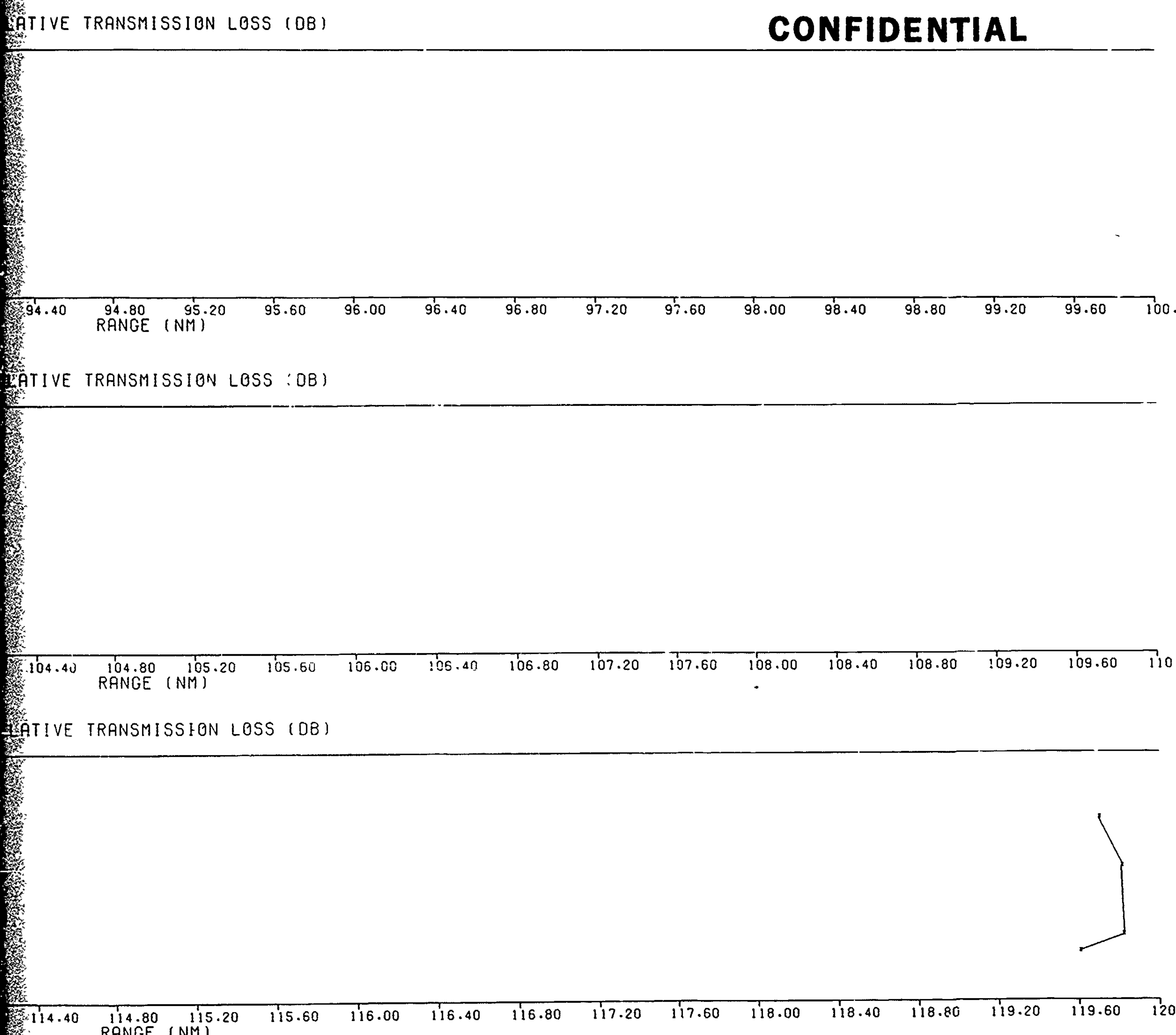
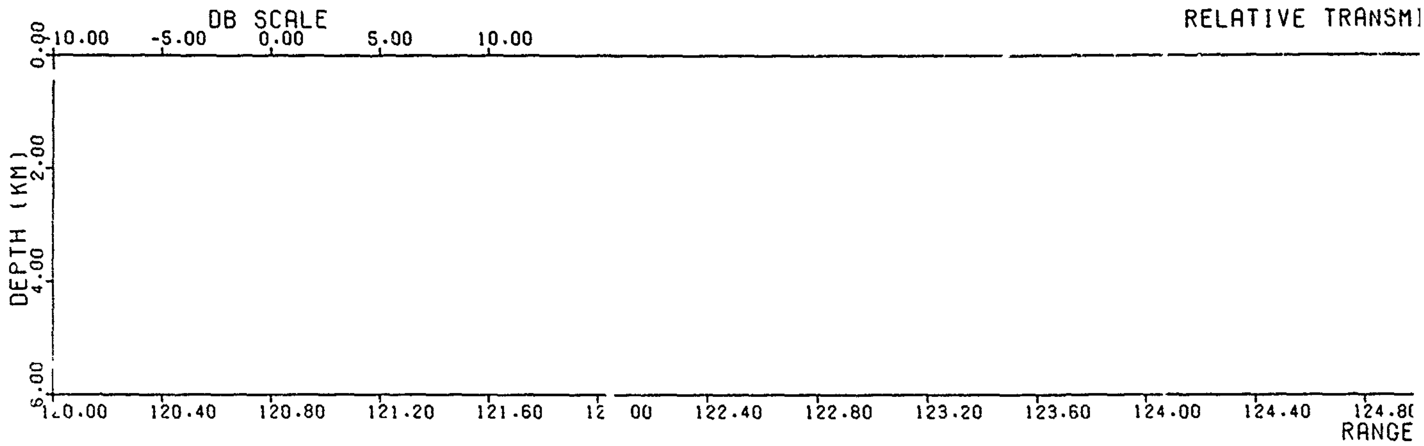


(C) Relative Transmission Loss Depth Profiles
at Posit B, 90-120 N. Miles, (NORTH SEAL SUS
Run E-B, Reference Depth 4806 Meters)

Figure 23

2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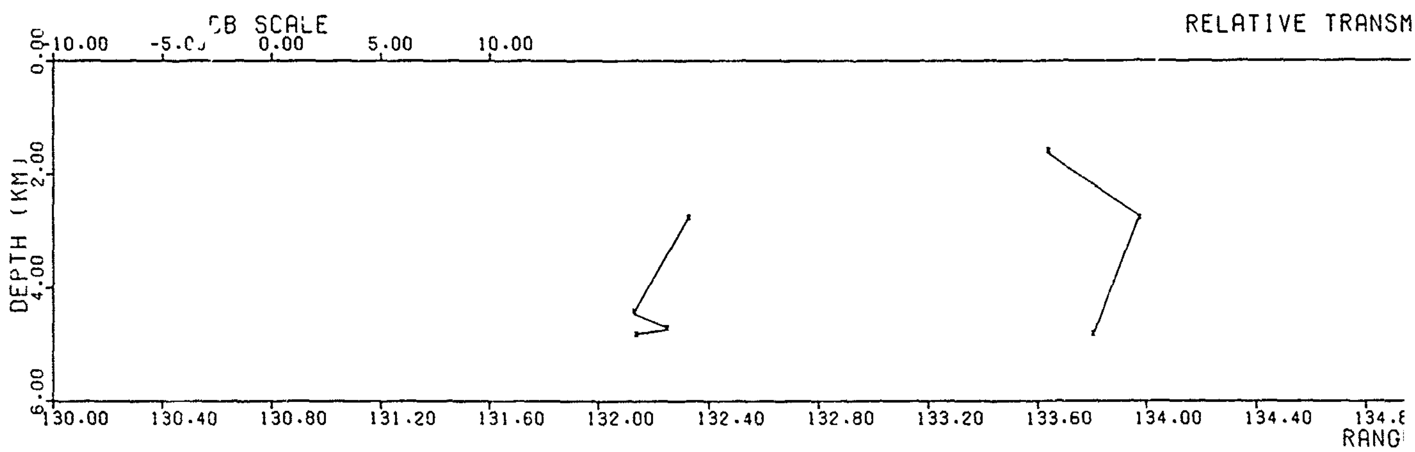
RANGE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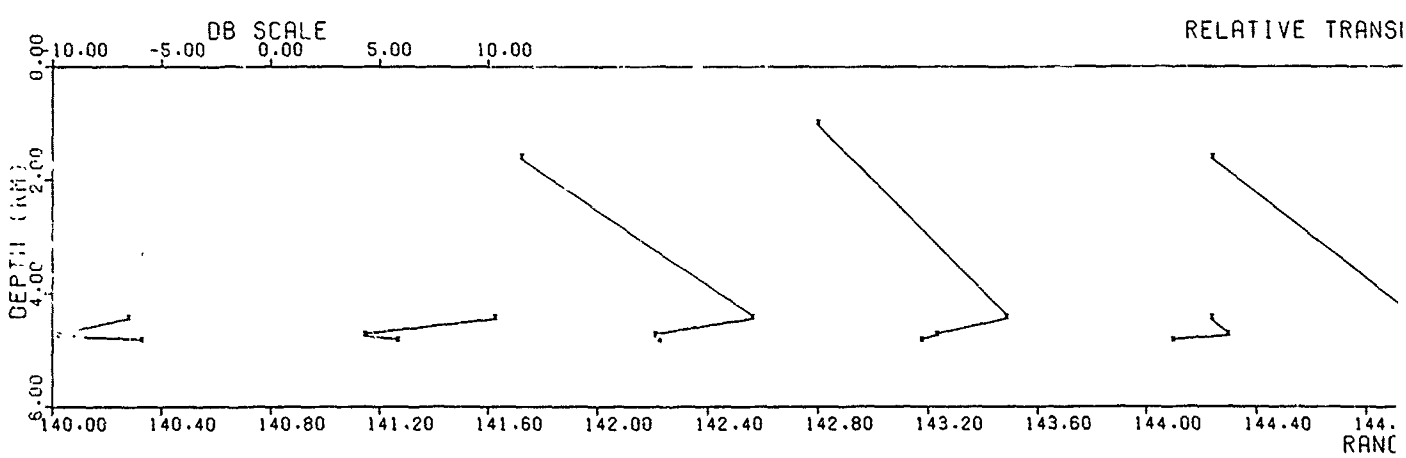
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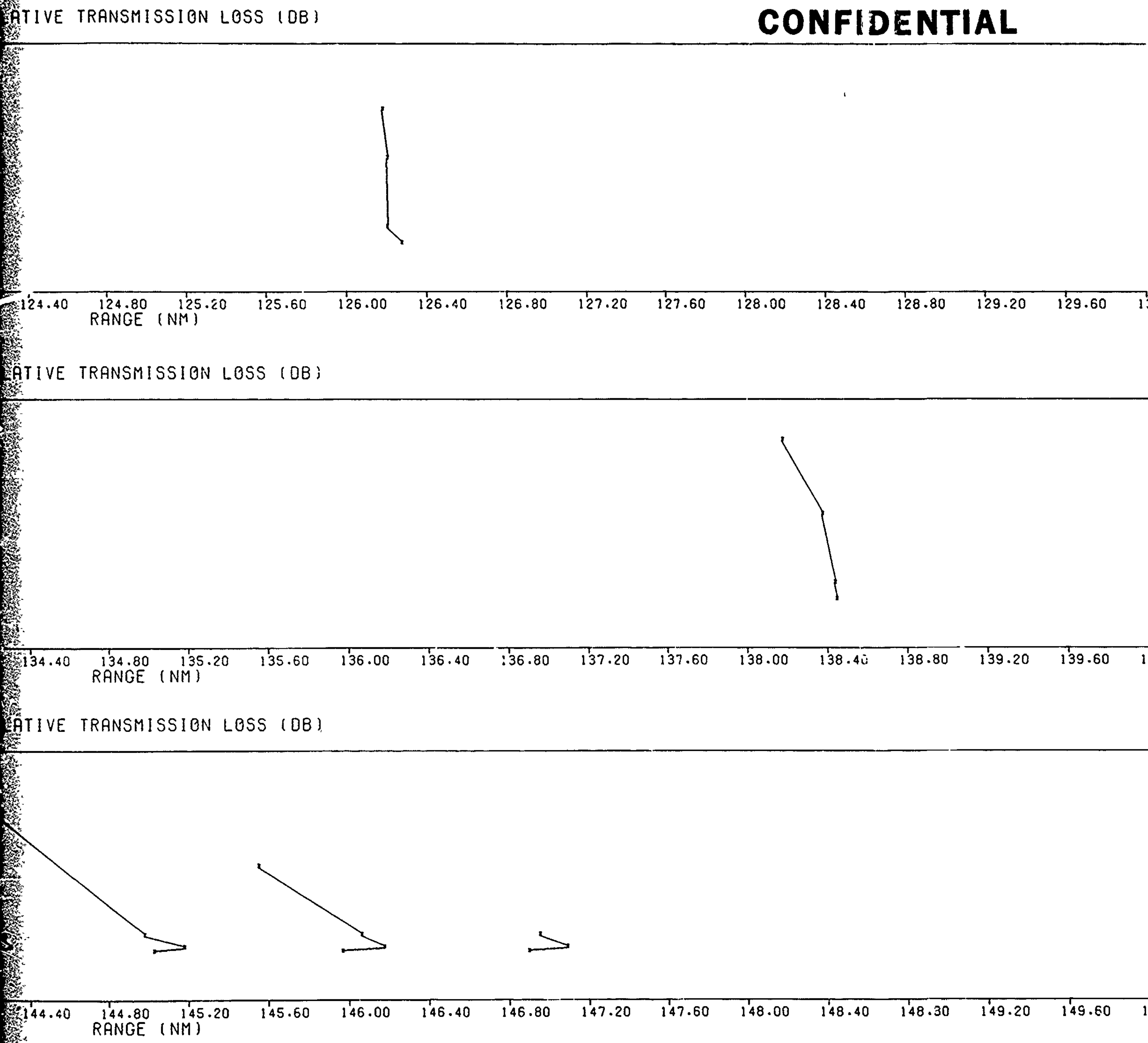
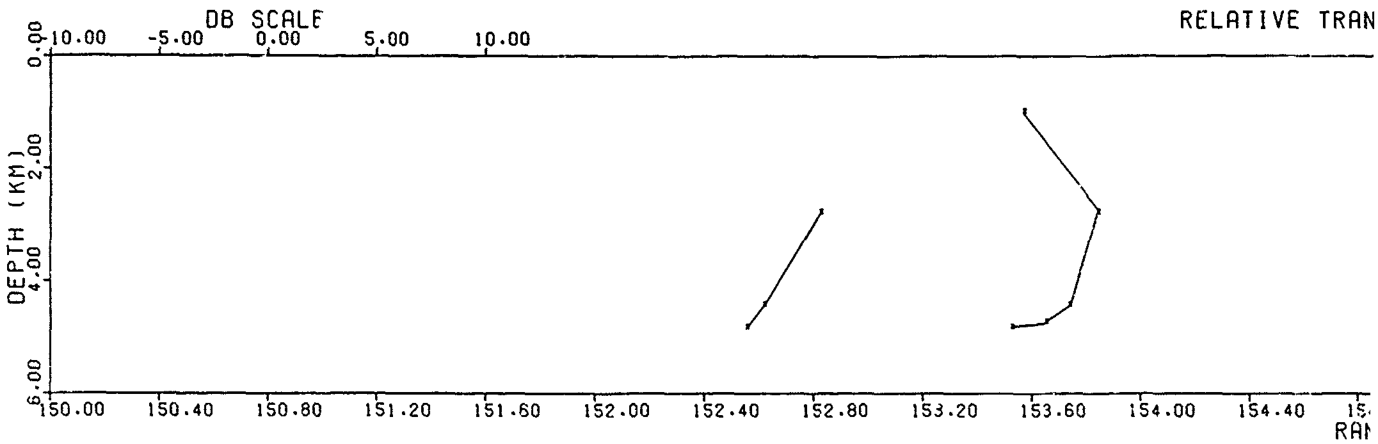


(C) Relative Transmission Loss Depth Profiles at Posit B, 120-150 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 24

2



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DEPTH (KM)
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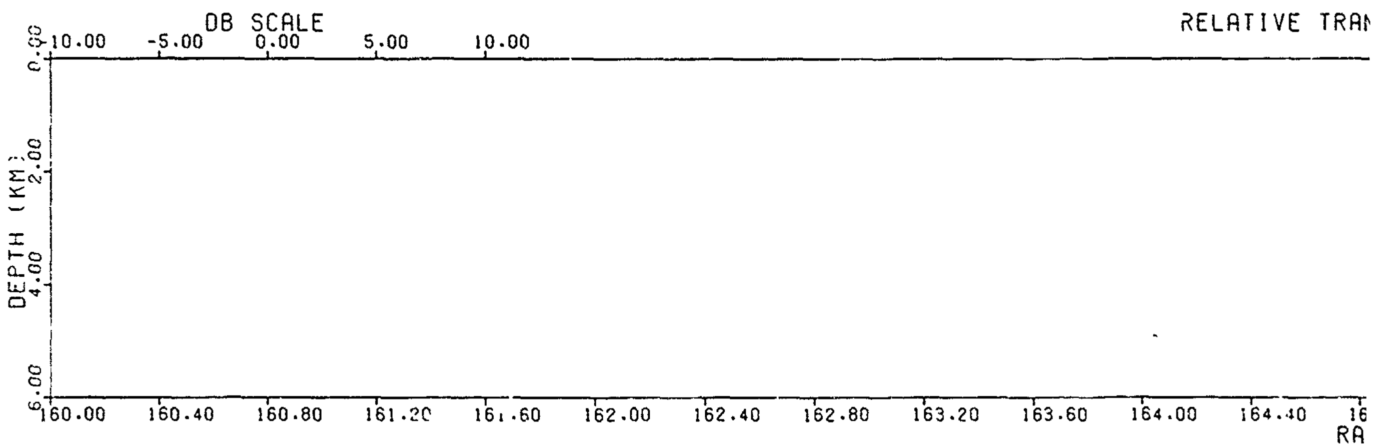
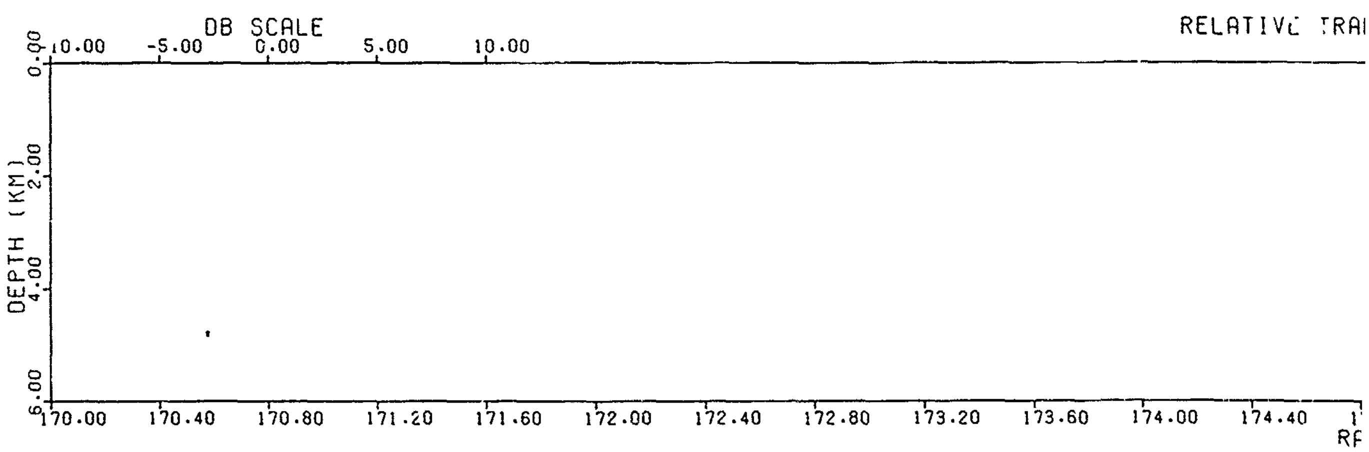
150.00 150.40 150.80 151.20 151.60 152.00 152.40 152.80 153.20 153.60 154.00 154.40
RAN



DB SCALE
-10.00 -5.00 0.00 5.00 10.00
RELATIVE TRAN
DEPTH (KM)
2.00 4.00 6.00
160.00 160.40 160.80 162.00 162.40 162.80 163.20 163.60 164.00
RA



DB SCALE
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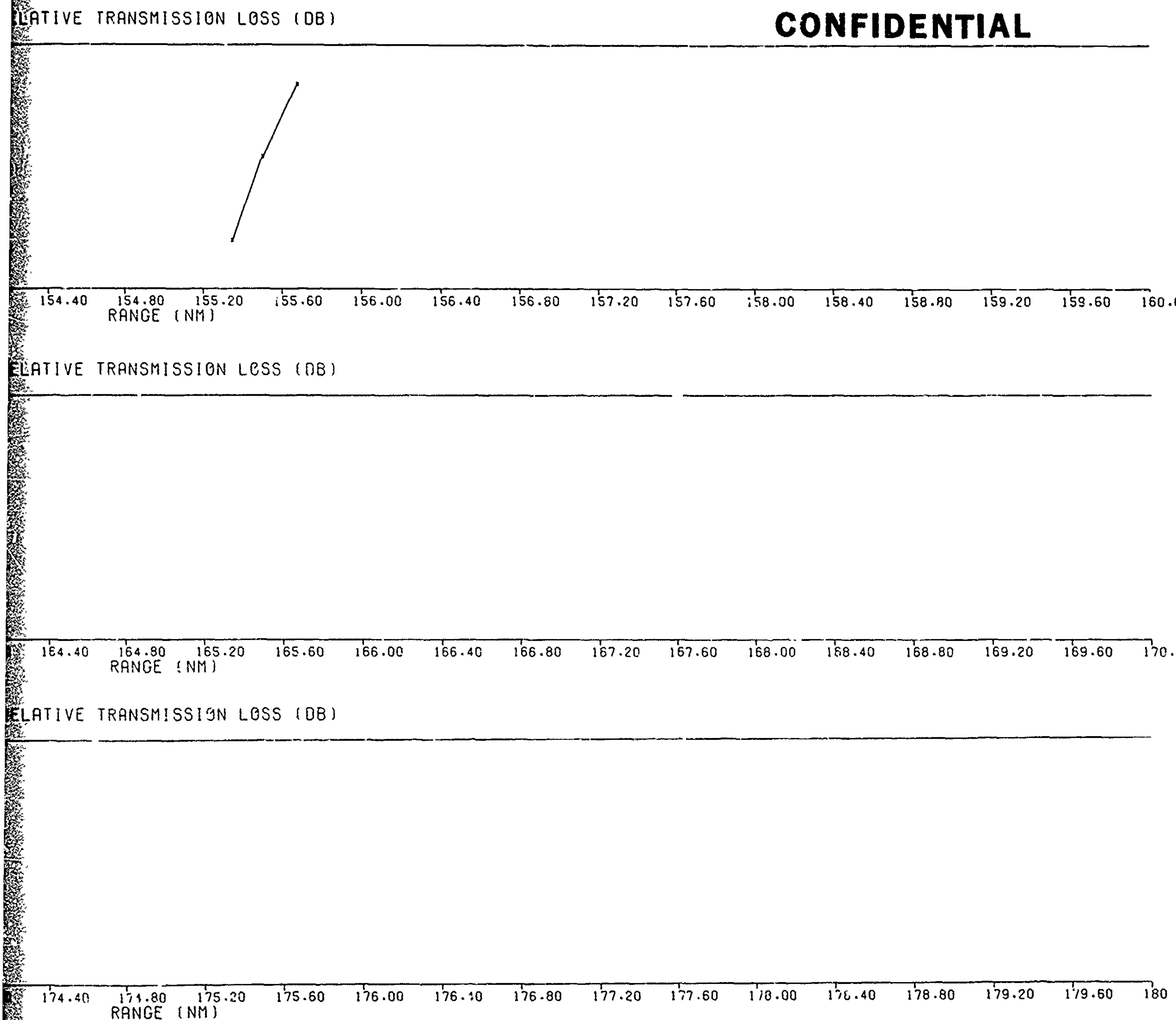
DEPTH (KM)
0.00 2.00 4.00 6.00
170.00 170.40 170.80 171.20 171.60 172.00 172.40 172.80 173.20 173.60 174.00 174.40

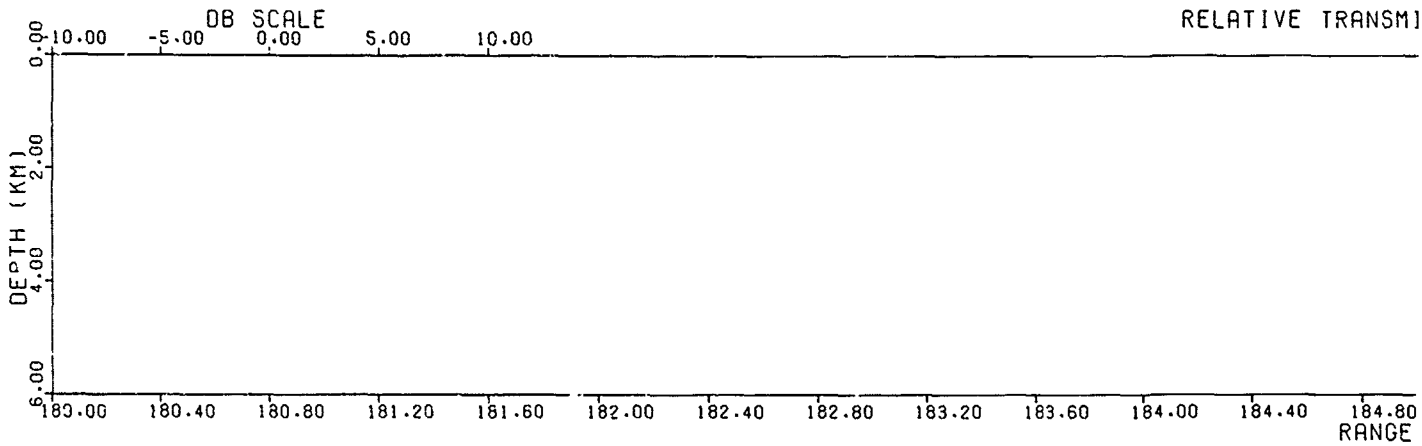
CONFIDENTIAL

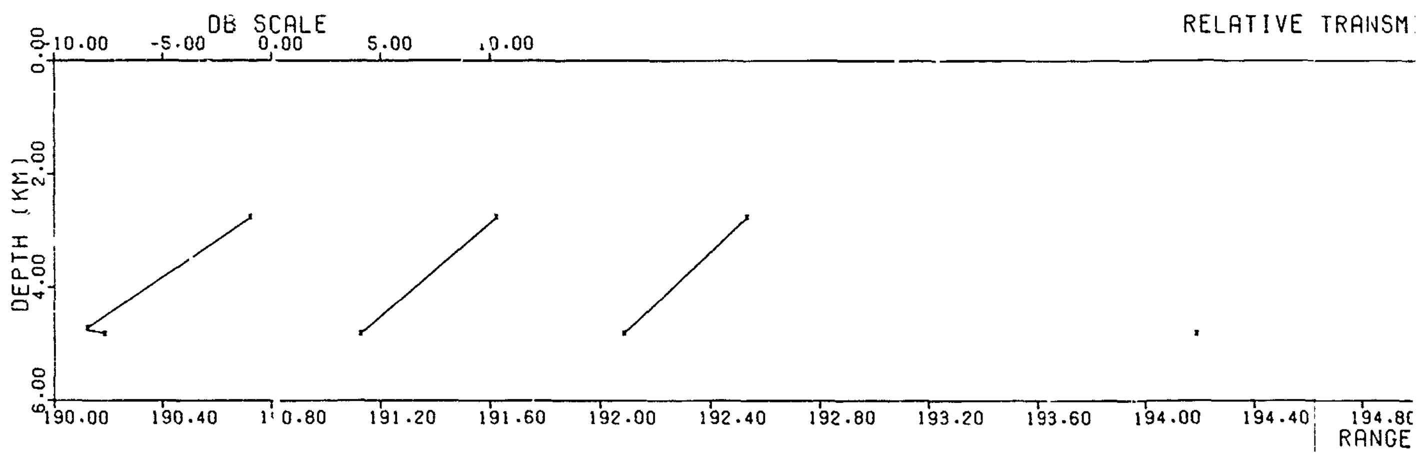


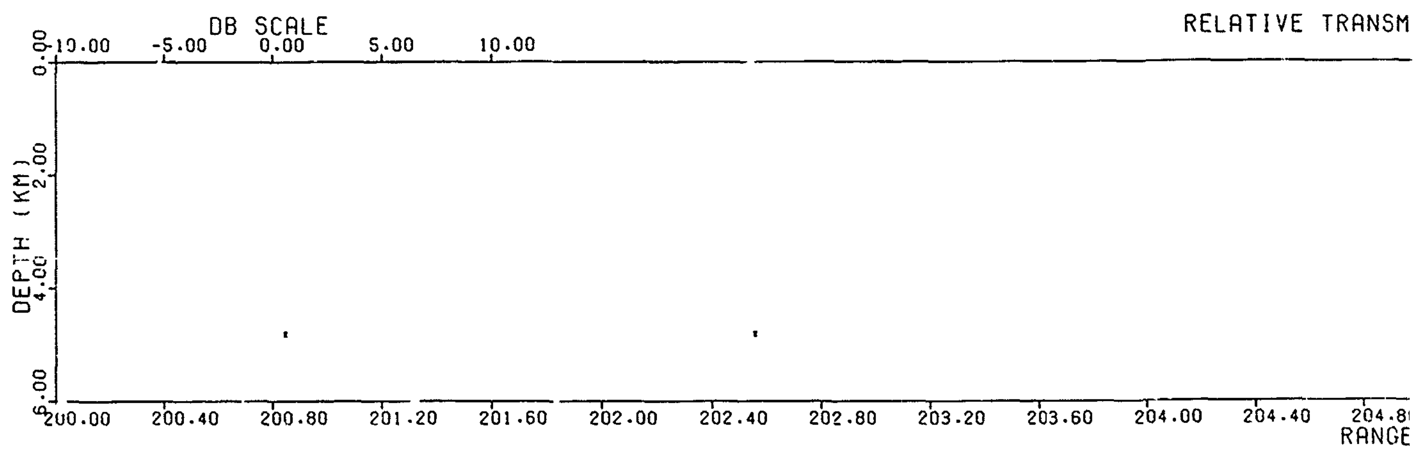
(C) Relative Transmission Loss Depth Profiles at Posit B, 150-180 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 25

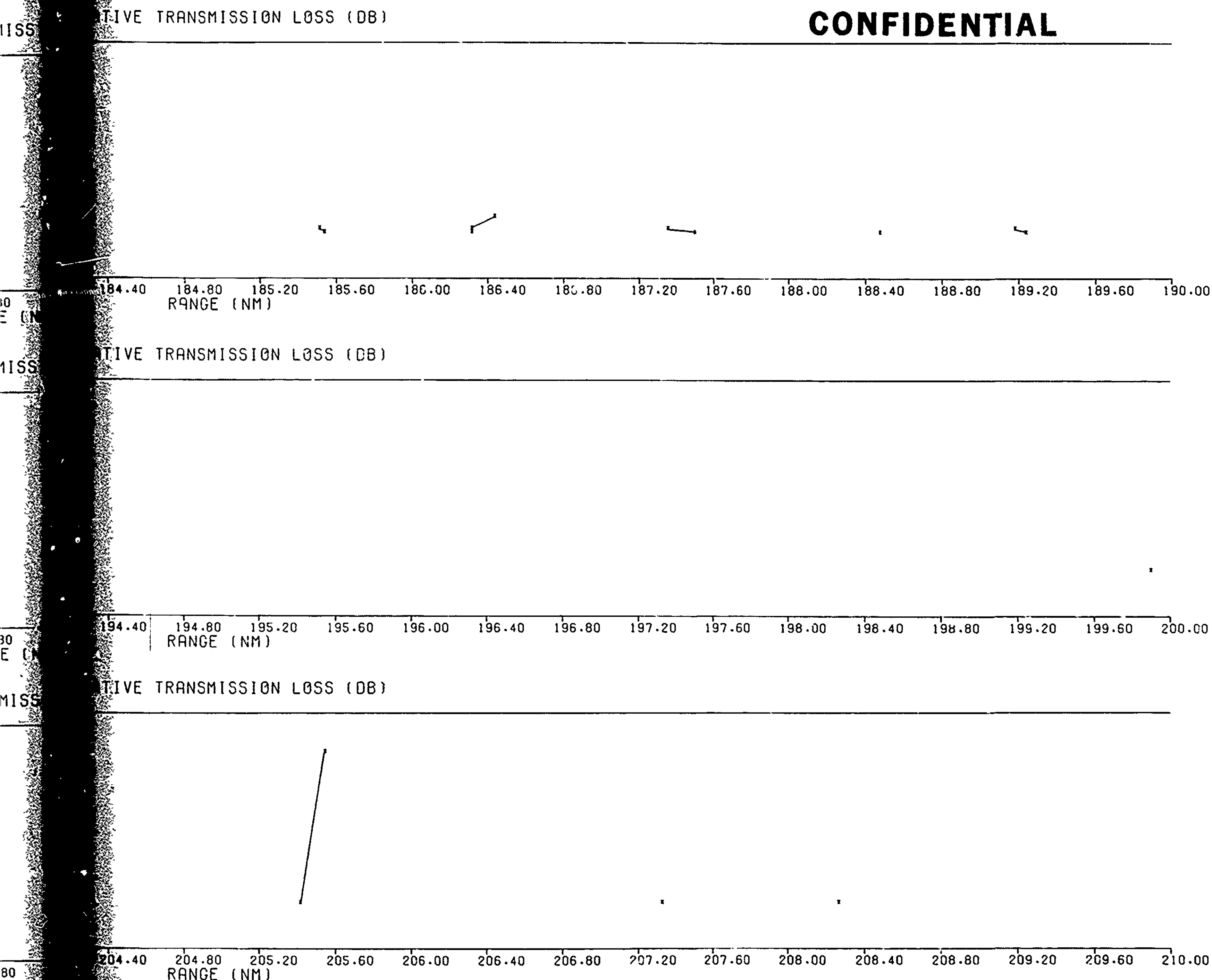
CONFIDENTIAL


DB SCALE
-10.00
-5.00
0.00
5.00
10.00
RELATIVE TRANSMI
DEPTH (KM)
0.00
2.00
4.00
6.00
180.00
180.40
180.80
181.20
181.60
182.00
182.40
182.80
183.20
183.60
184.00
184.40
184.80
RANGE


DB SCALE
-10.00
-5.00
0.00
5.00
10.00
RELATIVE TRANSM
DEPTH (KM)
0.00
2.00
4.00
6.00
190.00
190.40
191.20
191.60
192.00
192.40
192.80
193.20
193.60
194.00
194.40
RANGE


DB SCALE
-10.00
-5.00
0.00
5.00
10.00
RELATIVE TRANSM
DEPTH (KM)
0.00
2.00
4.00
6.00
200.00
200.40
200.80
201.20
201.60
202.00
202.40
202.80
203.20
203.60
204.00
204.40
RANGE

CONFIDENTIAL

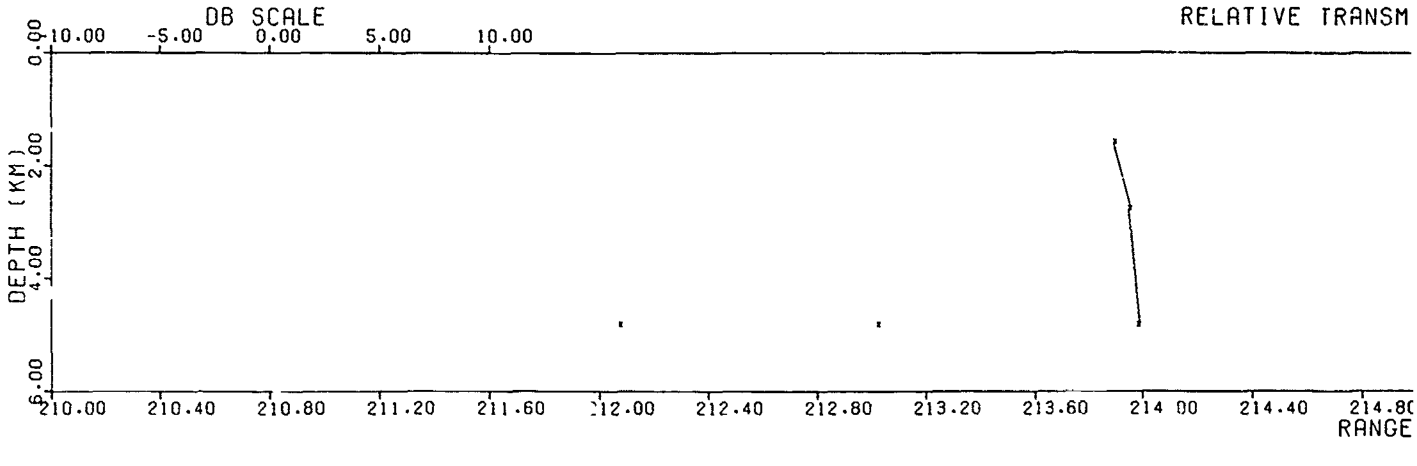


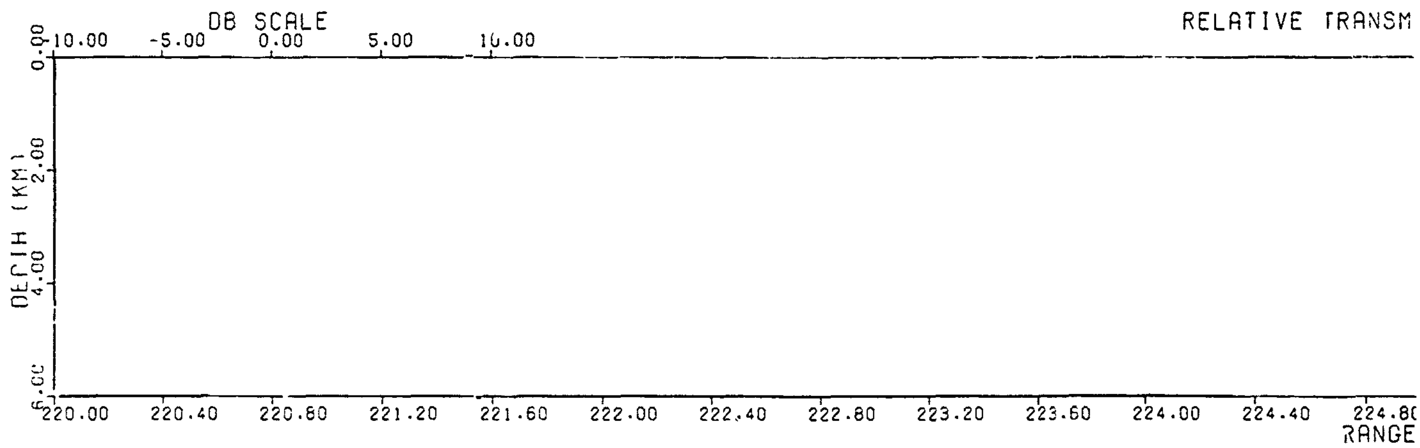
(C) Relative Transmission Loss Depth Profiles at Posit B, 180-210 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 1806 Meters)

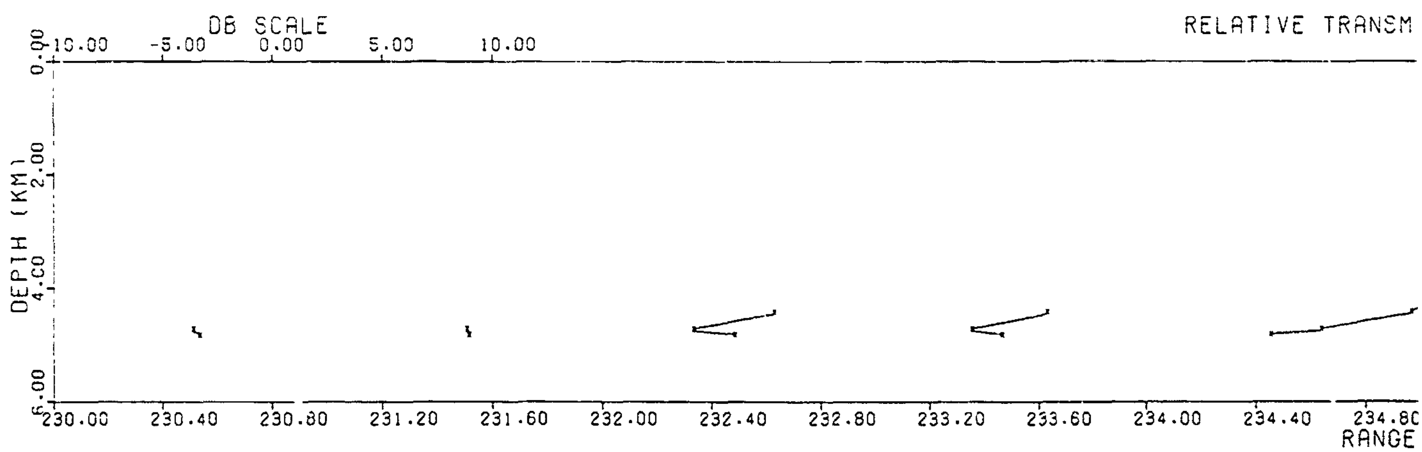
Figure 26

2

CONFIDENTIAL


DB SCALE
-10.00 -5.00 0.00 5.00 10.00
RELATIVE TRANSM
DEPTH (KM)
0.00 2.00 4.00 6.00
210.00 210.40 210.80 211.20 211.60 212.00 212.40 212.80 213.20 213.60 214.00 214.40 214.80
RANGE


DB SCALE
-10.00 -5.00 0.00 5.00 10.00
RELATIVE TRANSM
DEPTH (KM)
0.00 2.00 4.00 6.00
220.00 220.40 220.80 221.20 221.60 222.00 222.40 222.80 223.20 223.60 224.00 224.40 224.80
RANGE


DB SCALE
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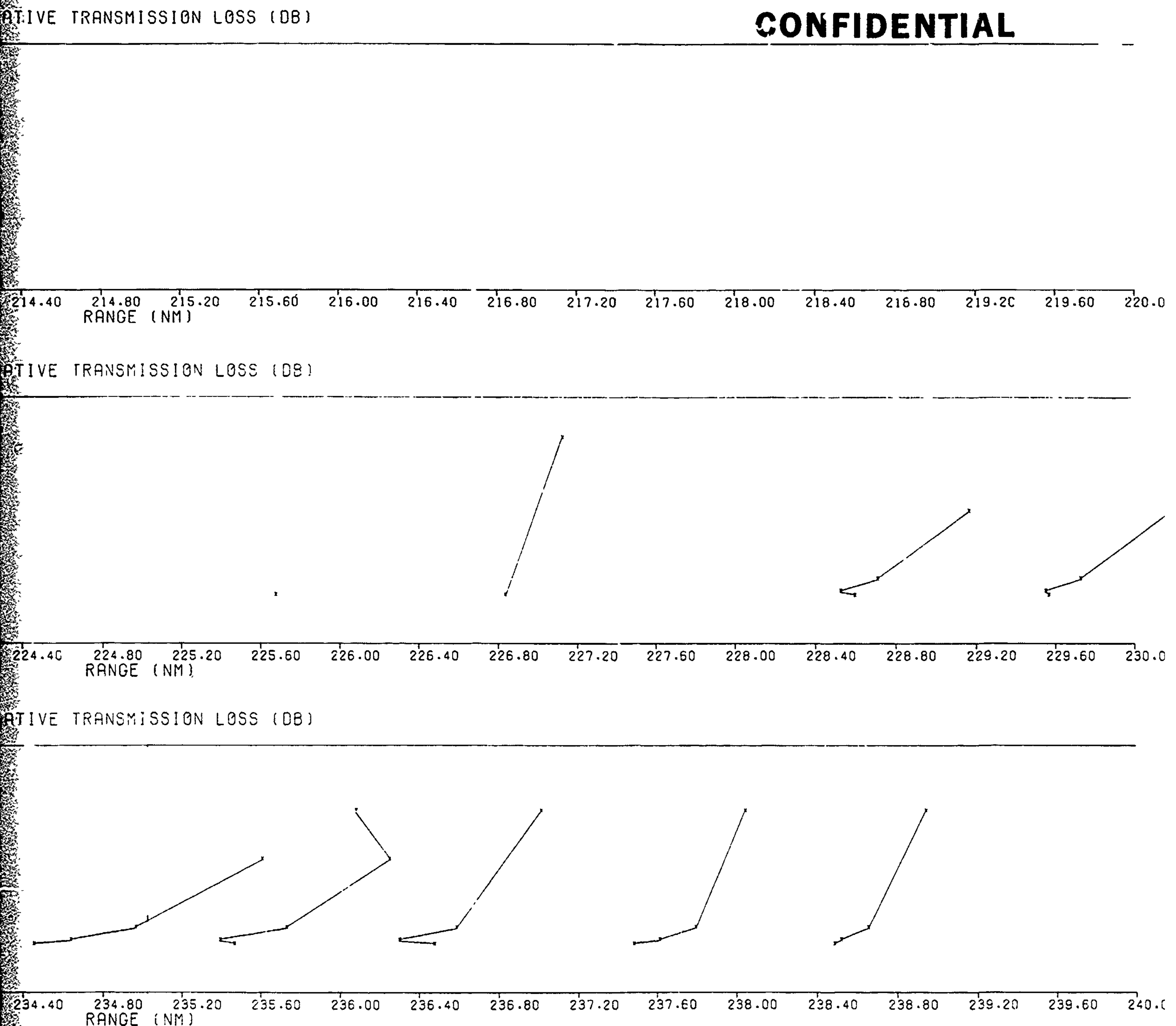
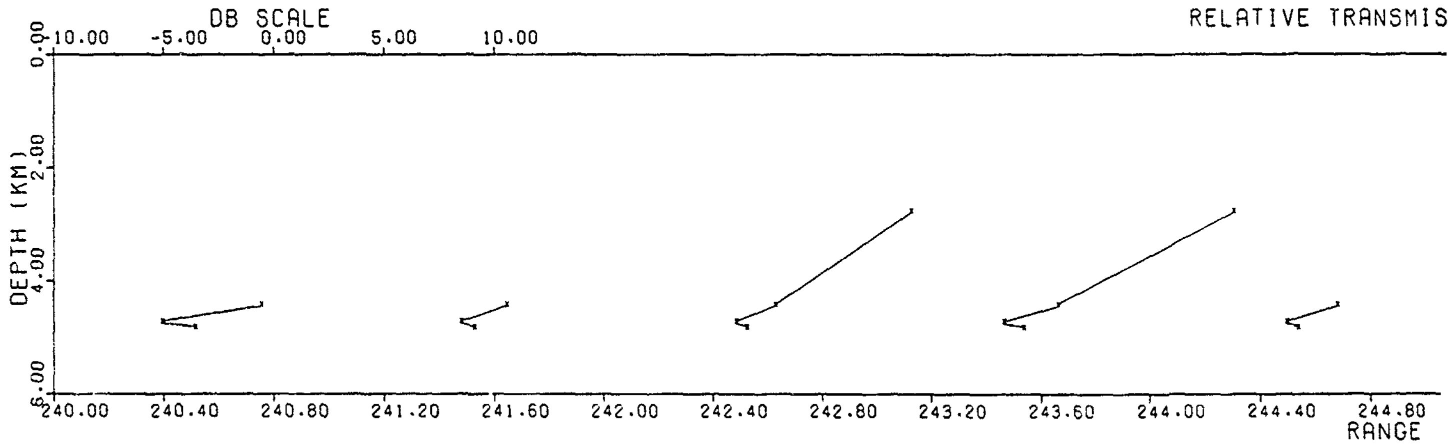
RELATIVE TRANSM
DEPTH (KM)
0.00 2.00 4.00 6.00
230.00 230.40 230.80 231.20 231.60 232.00 232.40 232.80 233.20 233.60 234.00 234.40 234.80
RANGE



(C) Relative Transmission Loss Depth Profiles at Posit B, 210-240 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 27

2


DB SCALE
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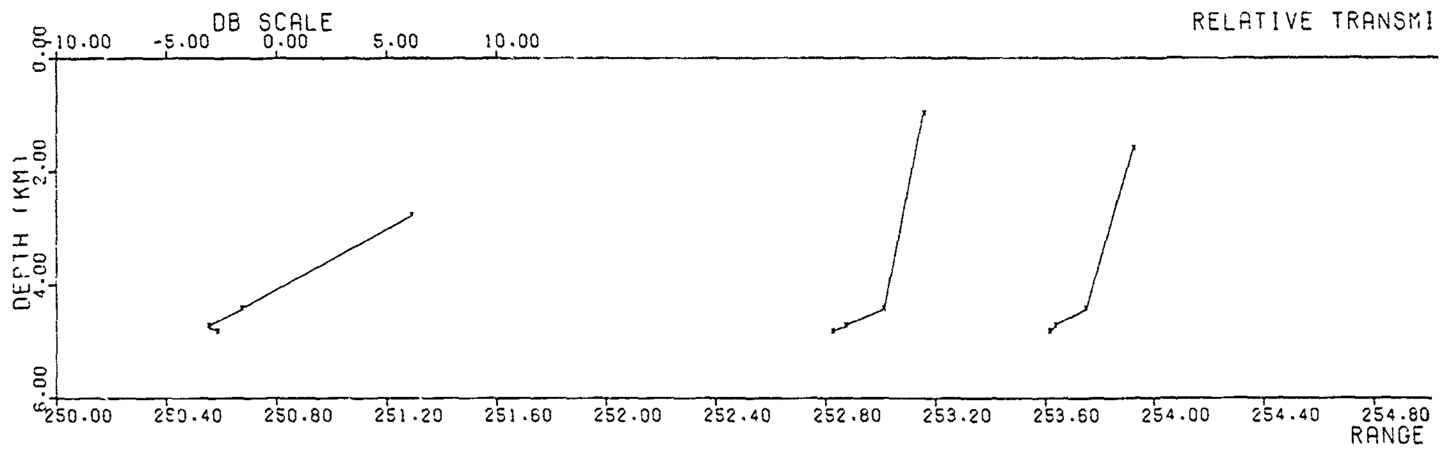
RELATIVE TRANSMIS
DEPTH (KM)
0.00 2.00 4.00 6.00
240.00 240.40 240.80 241.20 241.60 242.00 242.40 242.80 243.20 243.60 244.00 244.40 244.80
RANGE


DB SCALE
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RELATIVE TRANSMI
DEPTH (KM)
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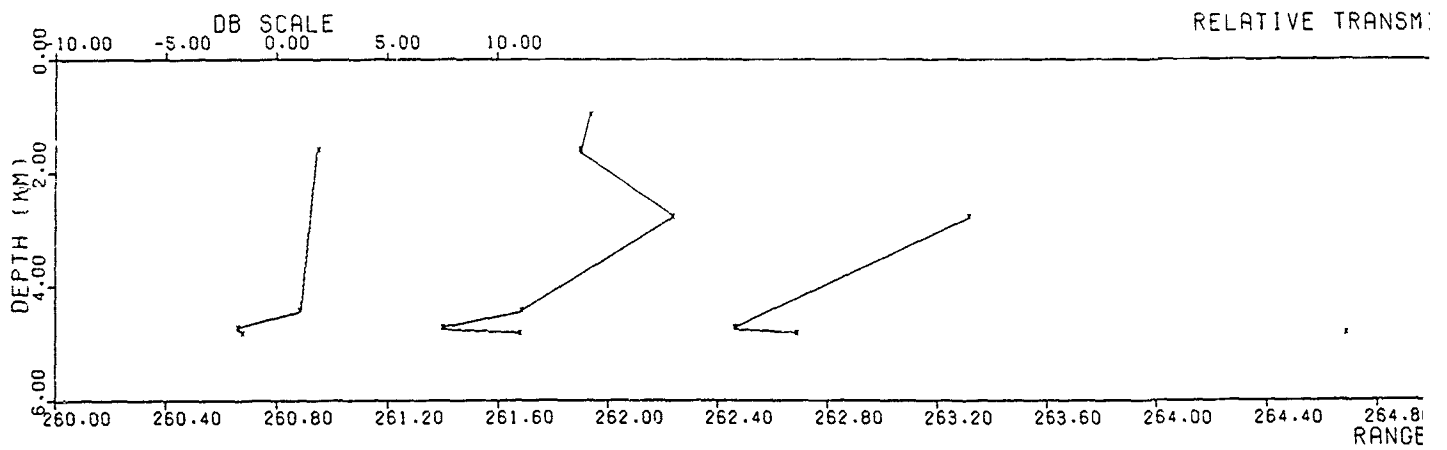
RANGE


DB SCALE
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RELATIVE TRANSM
DEPTH (KM)
0.00 2.00 4.00 6.00
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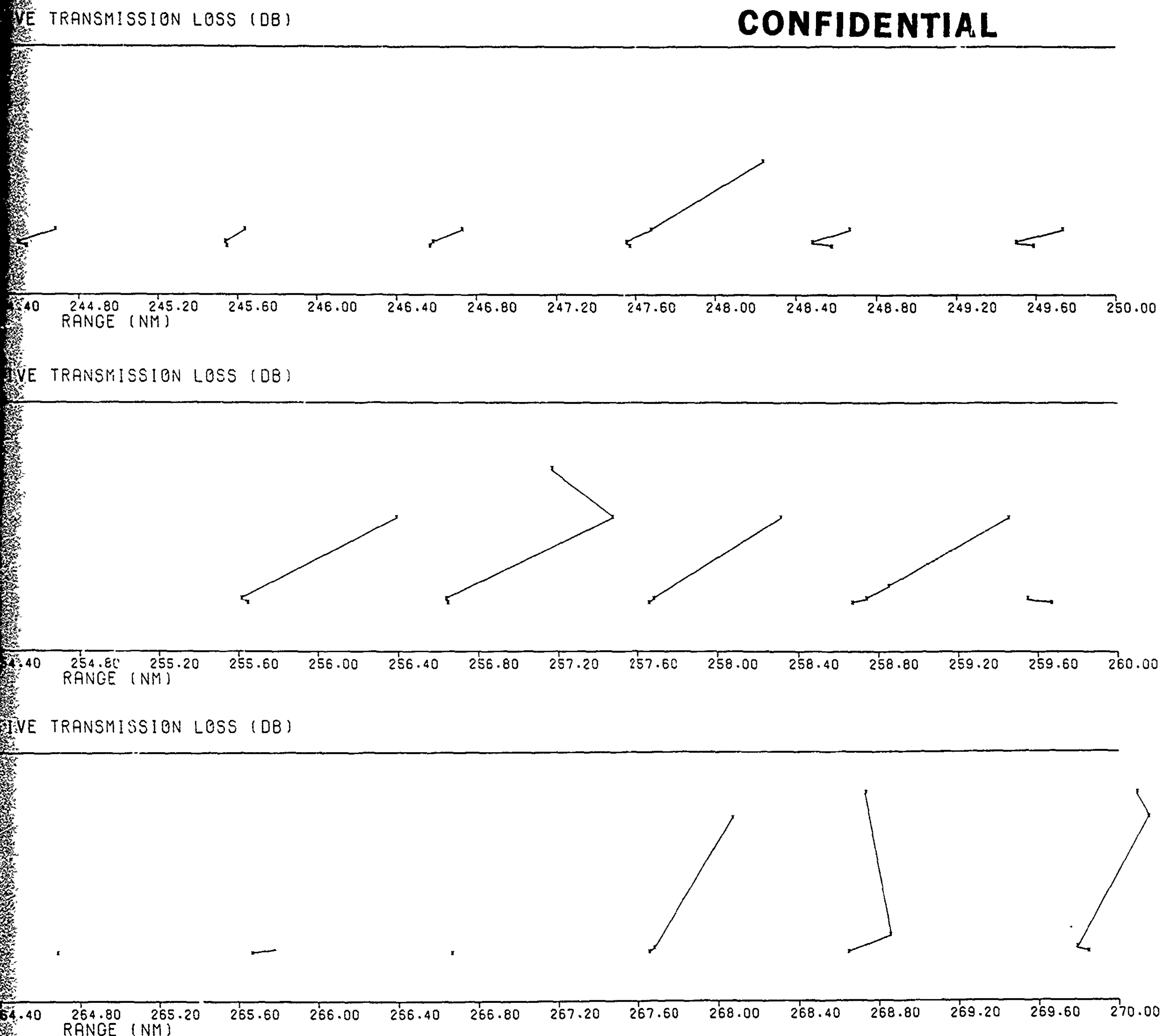
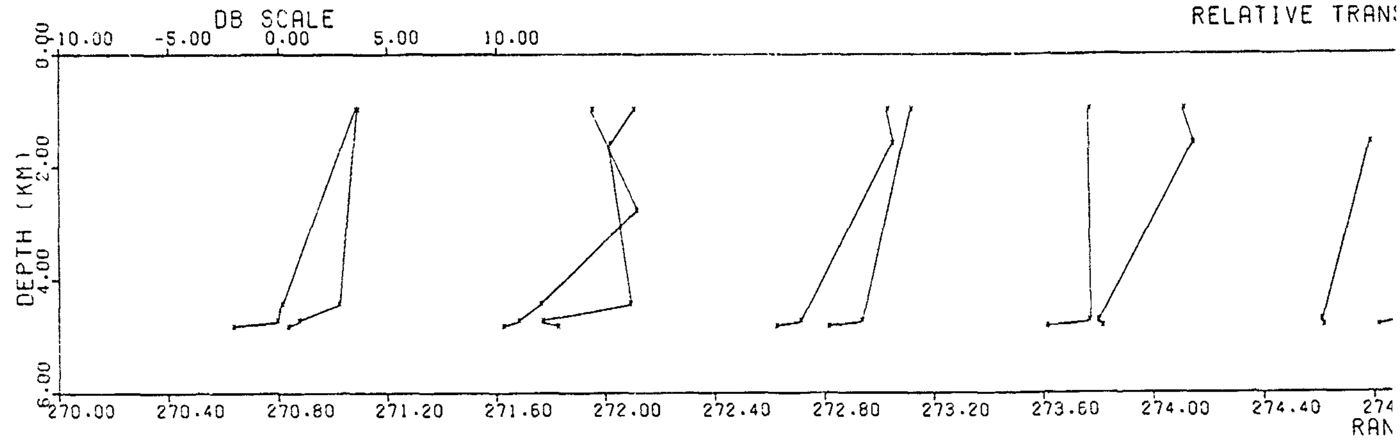
RANGE

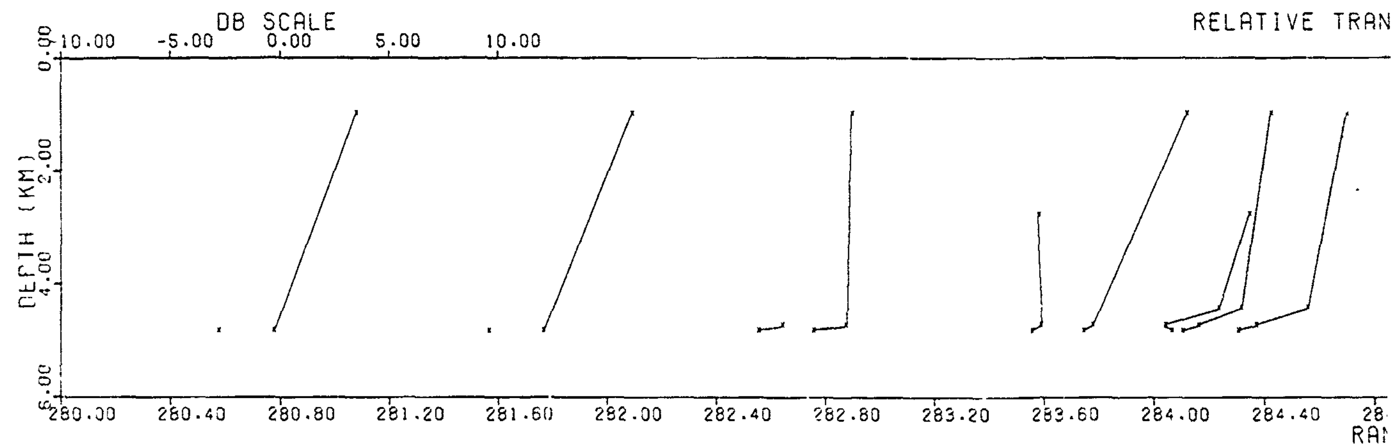


(C) Relative Transmission Loss Depth Profiles at Posit B, 240-270 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 28

2


DB SCALE
-10.00 -5.00 0.00 5.00 10.00
RELATIVE TRANS
DEPTH (KM)
0.00 2.00 4.00 6.00
270.00 270.40 270.80 271.20 271.60 272.00 272.40 272.80 273.20 273.60 274.00 274.40 274
RAN


DB SCALE
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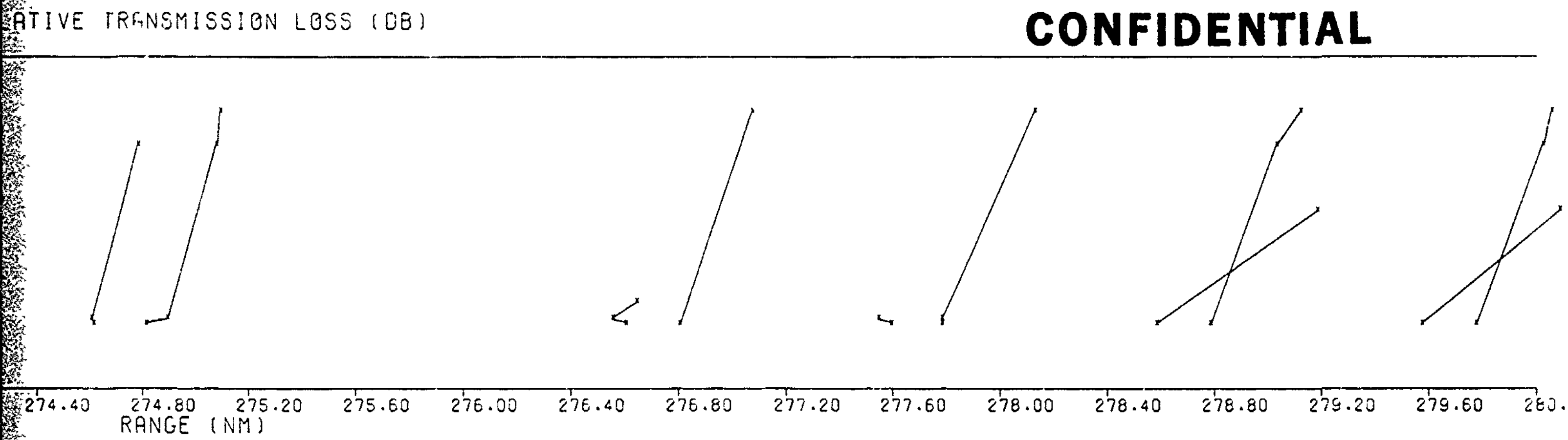
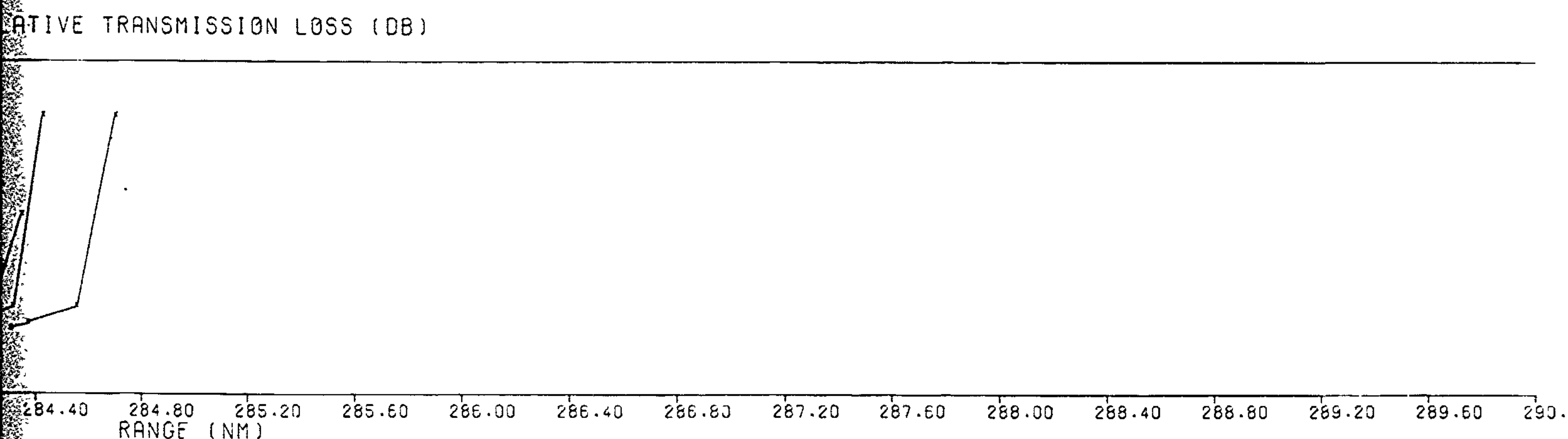
RELATIVE TRAN
DEPTH (KM)
0.00 2.00 4.00 6.00
280.00 280.40 280.80 281.20 281.60 282.00 282.40 282.80 283.20 283.60 284.00 284.40 28
RA





(C) Relative Transmission Loss Depth Profiles at Posit B, 270-290 N. Miles, (NORTH SEAL SUS Run E-B, Reference Depth 4806 Meters)

Figure 29

2

ACKNOWLEDGMENT

Several persons and organizations participated in the processing of data on which this report is based. I wish to note particularly the efforts of Dr. Earl Hays, Messrs. Stanley Berstrom, Gordon Glass, Richard Nowak, Jess Stanbrough and Constantine Tollios of the Woods Hole Oceanographic Institution; the efforts of Dr. Loyd Hampton, Messrs. Glenn Ellis and Jack Shooter of the Applied Research Laboratory, University of Texas; the efforts of Mr. Robert LaPlante of the Naval Underwater Systems Center, New London Laboratory; and the efforts of Mr. Kenneth Lackie of the Naval Oceanographic Office who coordinated the assistance of that organization in the preparation of ship and aircraft tracks, track charts, area charts and environmental data. To all of these and others who contributed I extend my appreciation and thanks.

Scott C. Daubin
24 June 1974

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4. S. C. Daubin, "Ambient Noise in the Northwest Caribbean (U)" CHURCH GABBRO Technical Note, University of Miami Technical Report (CONFIDENTIAL).

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7. Naval Oceanographic Office, "Environmental - Acoustic Atlas of the Caribbean Sea and Gulf of Mexico", Vol. I - Marine Acoustics (U), August 1972 USNOO SP-189 I (CONFIDENTIAL).

8. C. D. Tollios, "The ACODAC Data Processing System", Woods Hole Oceanographic Institution Technical Report WHOI-73-59, September 1973.

9. University of Texas, Applied Research Laboratory, "Low Frequency Sound Propagation in the Cayman Trough".

APPENDIX A

-

TRANSMISSION LOSS COMPUTED FROM

NORTH SEAL SUS RUN DATA

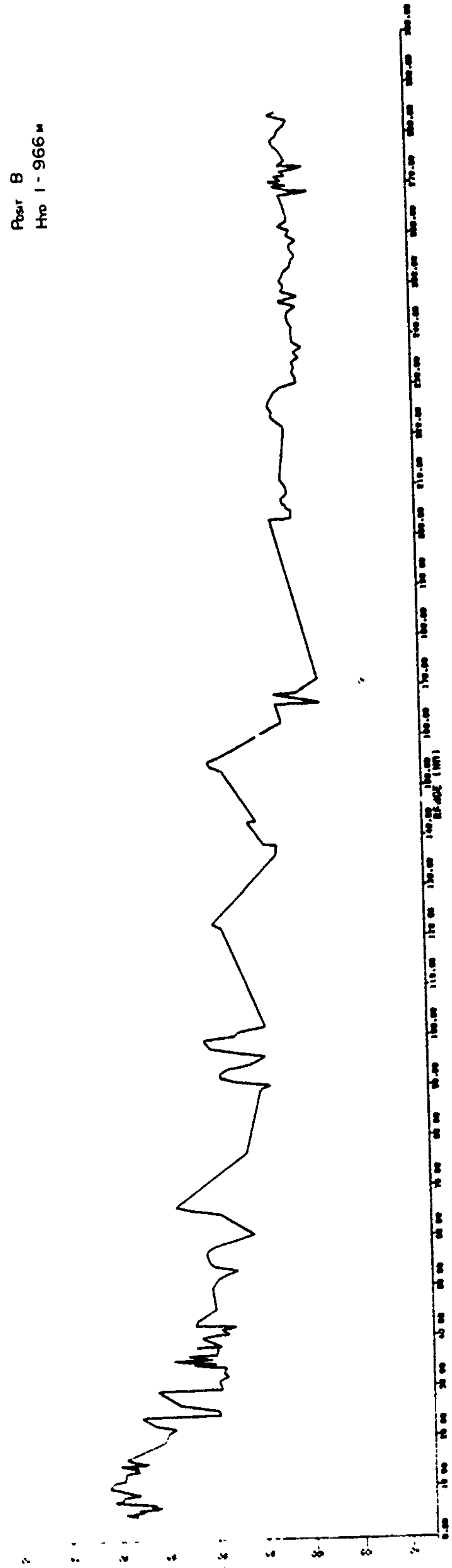
FROM POSIT E

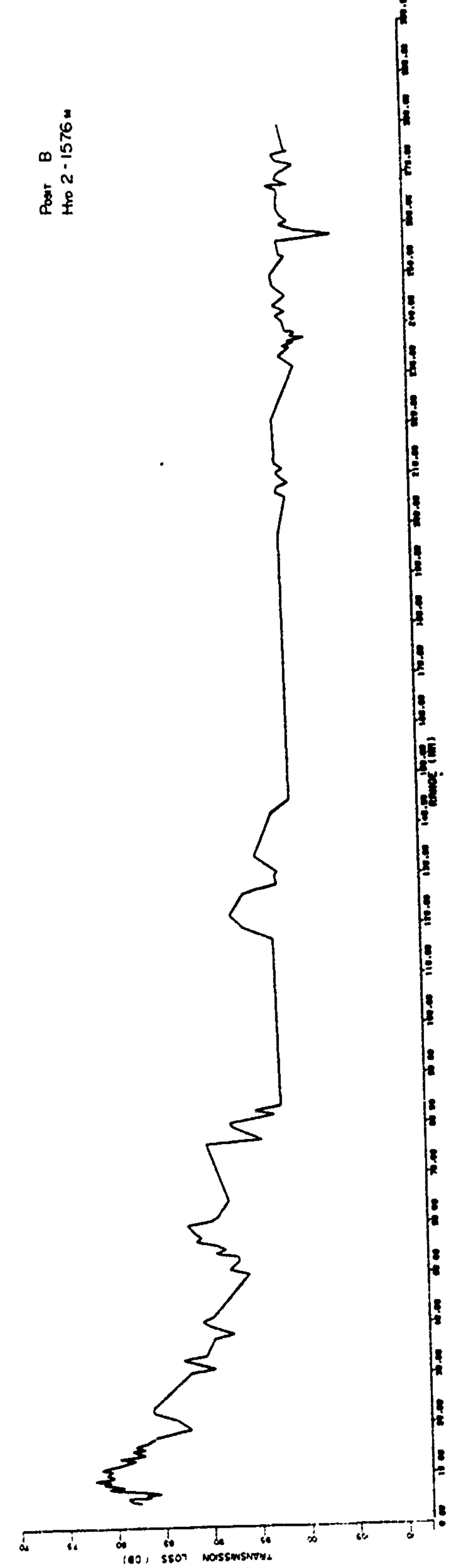
TO POSIT B

-

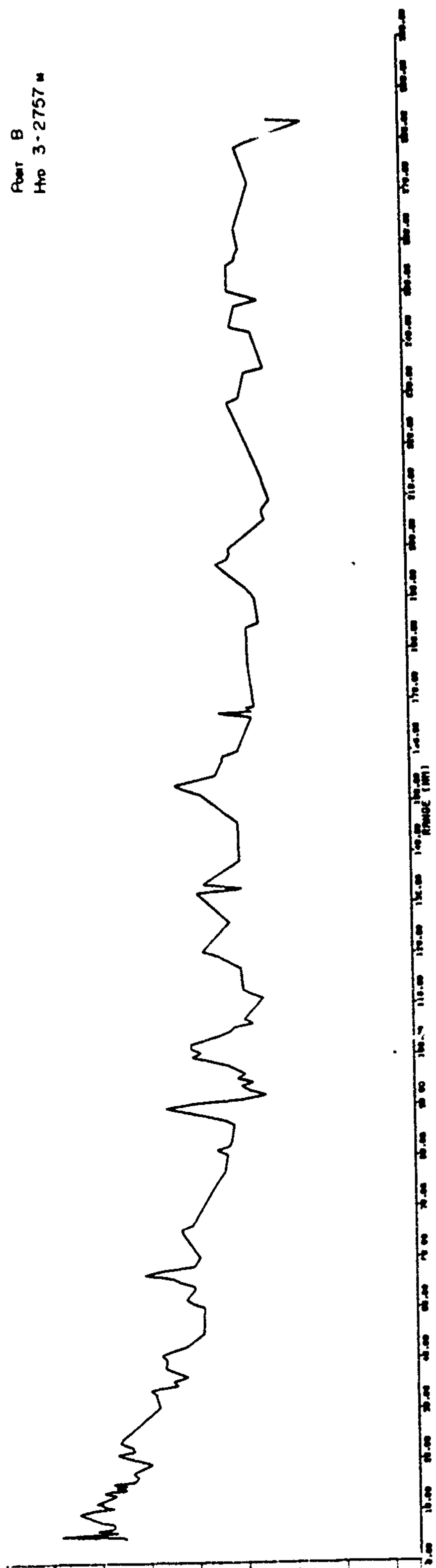
RECEIVING SYSTEM ACODAC AT POSIT B

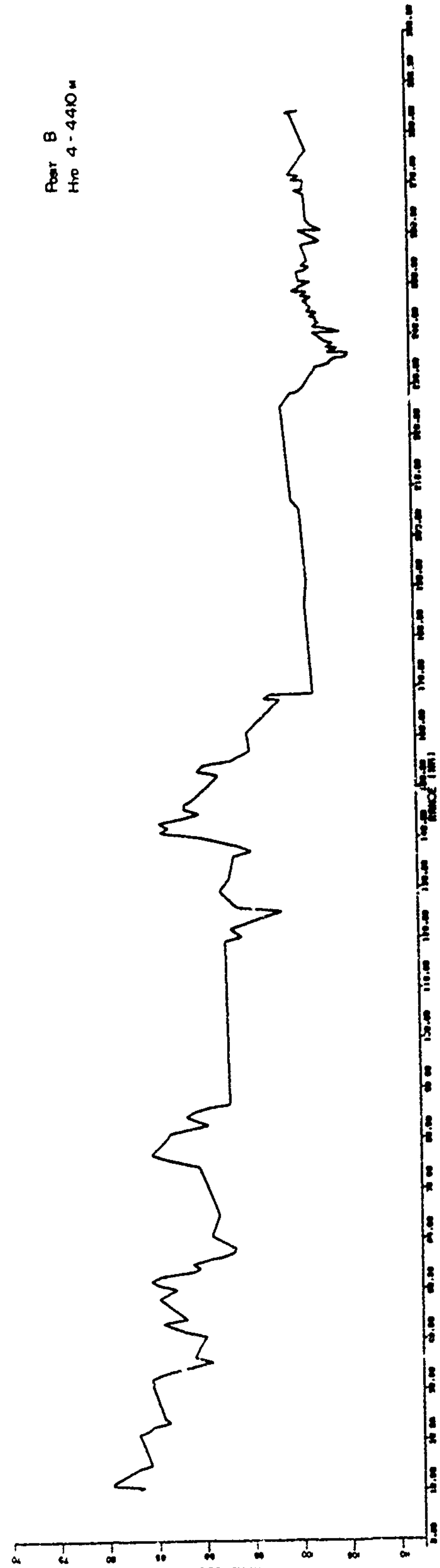
Contents: Pages:


Post B
Hyd 1 - 966 m


Post B
Hyd 2 - 1576 m
TRANSMISSION LOSS (DB)

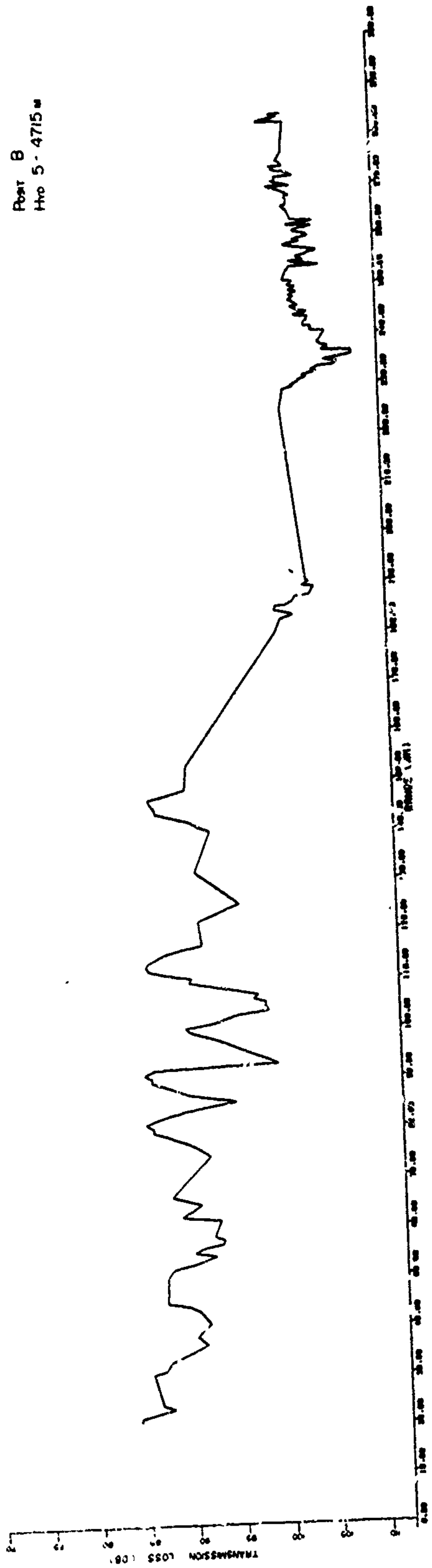
CONFIDENTIAL

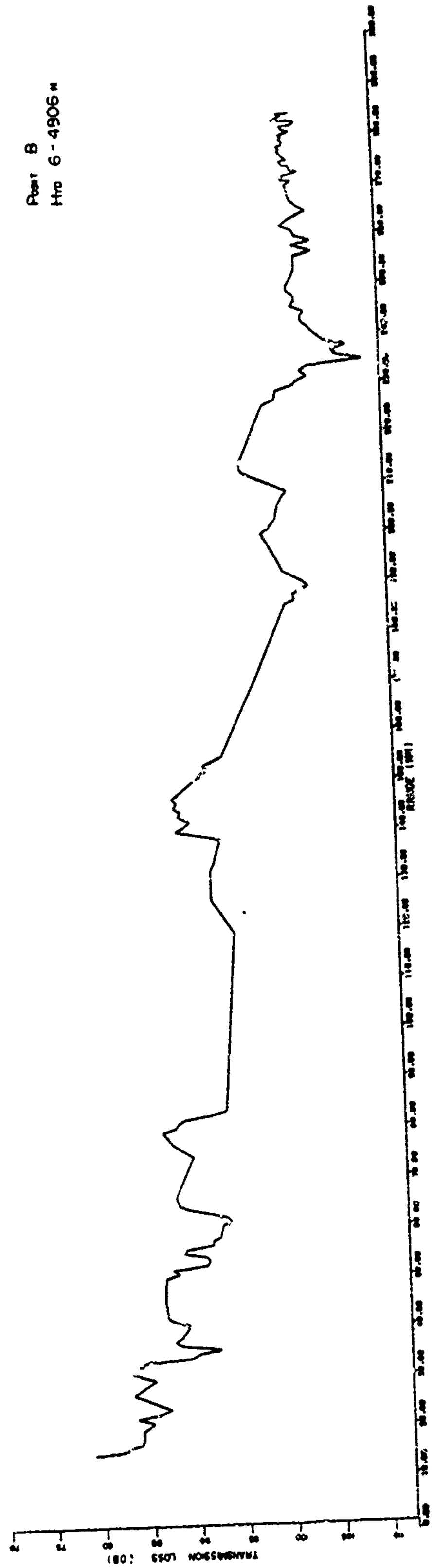


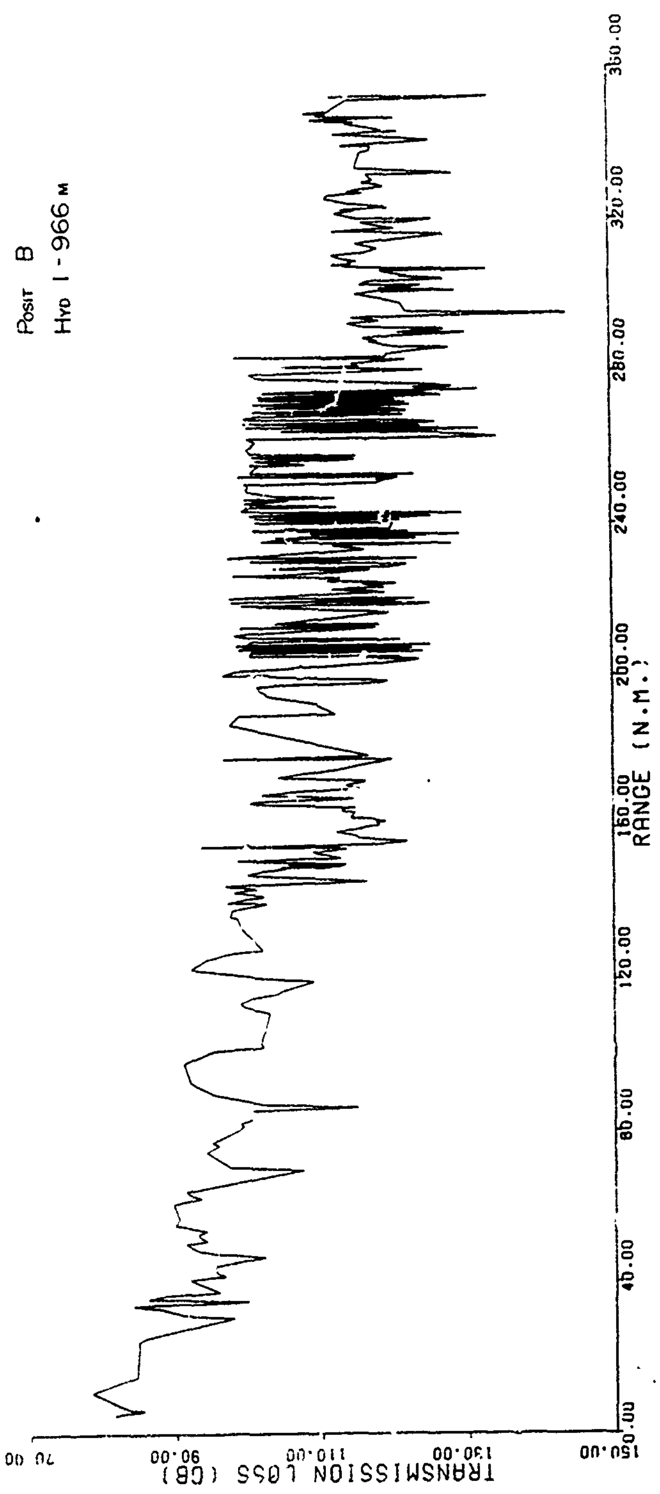


CONFIDENTIAL

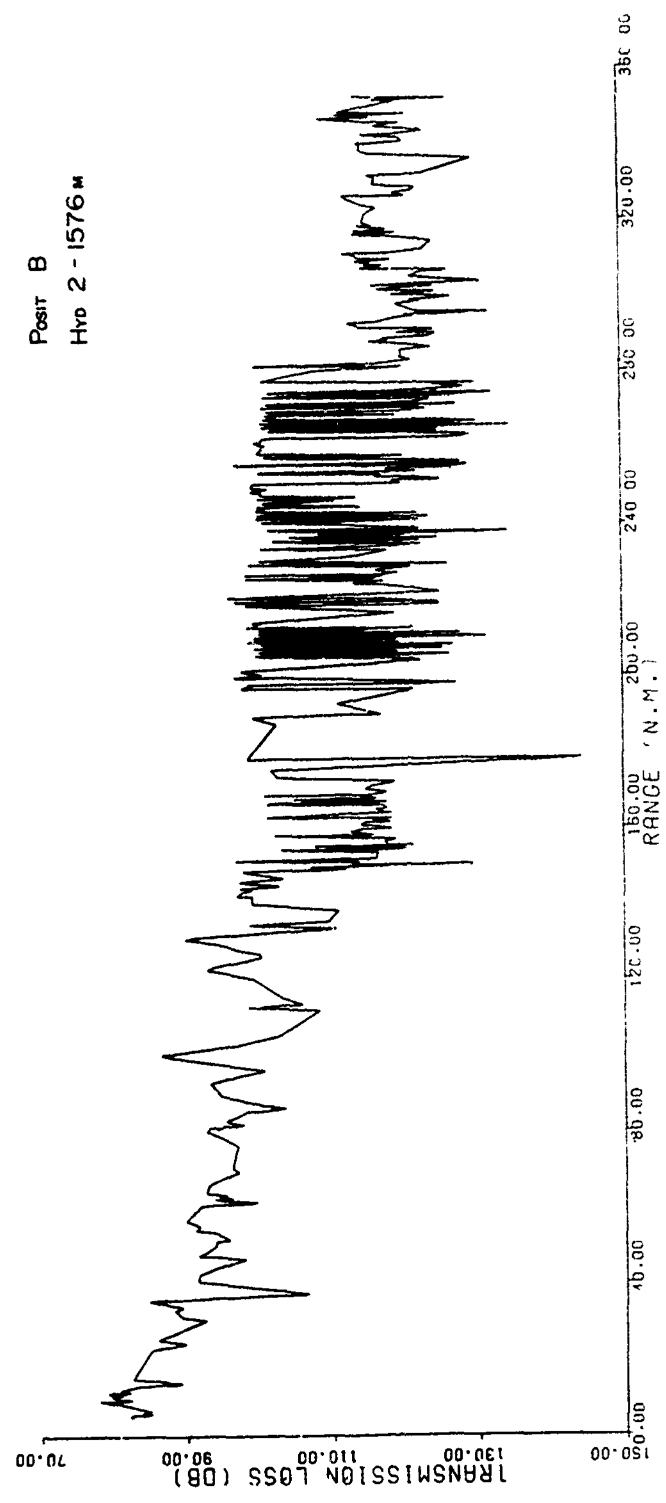
CONFIDENTIAL



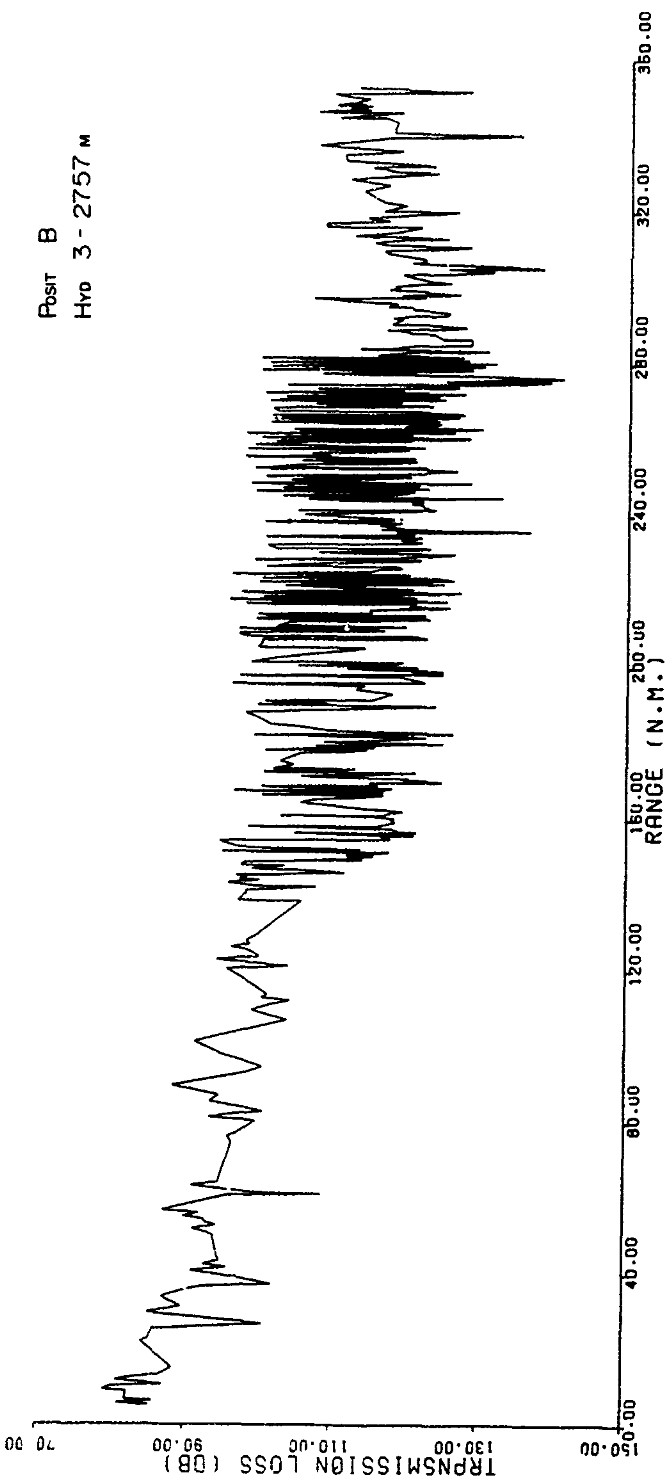




Posit B
Hyd 1 - 966 m
RANGE (N.M.)
TRANSMISSION LOSS (DB)



Posit B
Hyd 2 - 1576 m
RANGE (N.M.)
TRANSMISSION LOSS (DB)



POSIT B
HYD 3-2757 M
RANGE (N.M.)
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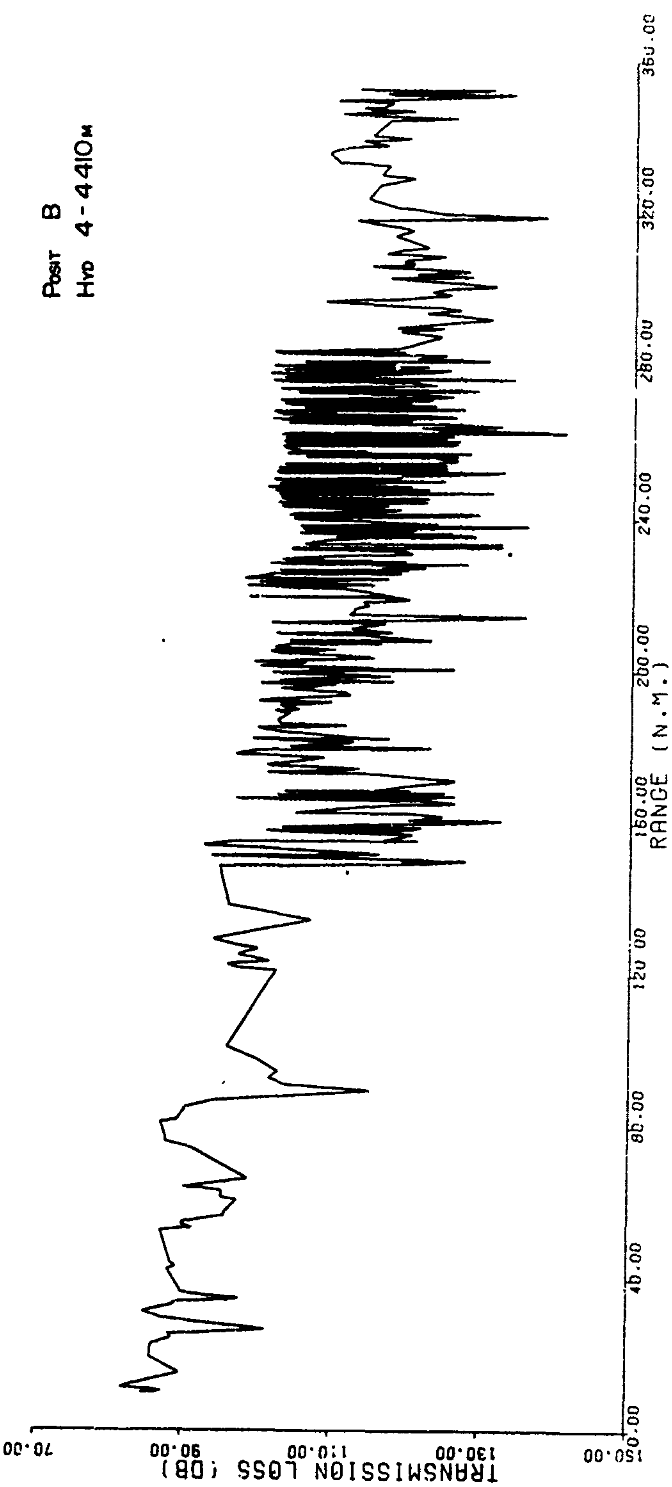
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
TRANSMISSION LOSS (DB)
70.00
90.00
110.00
130.00
150.00



POSIT B
HYD 4-4410M
RANGE (N.M.)
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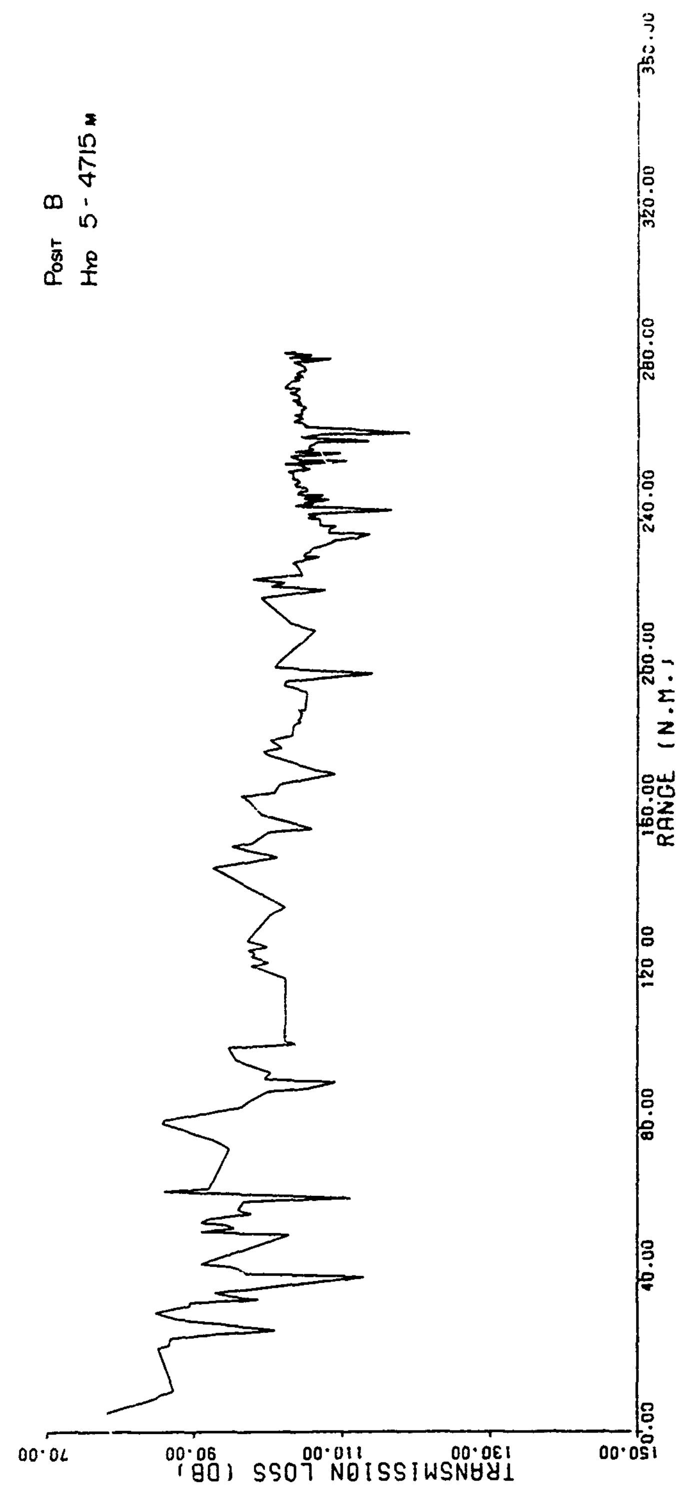
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
TRANSMISSION LOSS (DB)
70.00
90.00
110.00
130.00
150.00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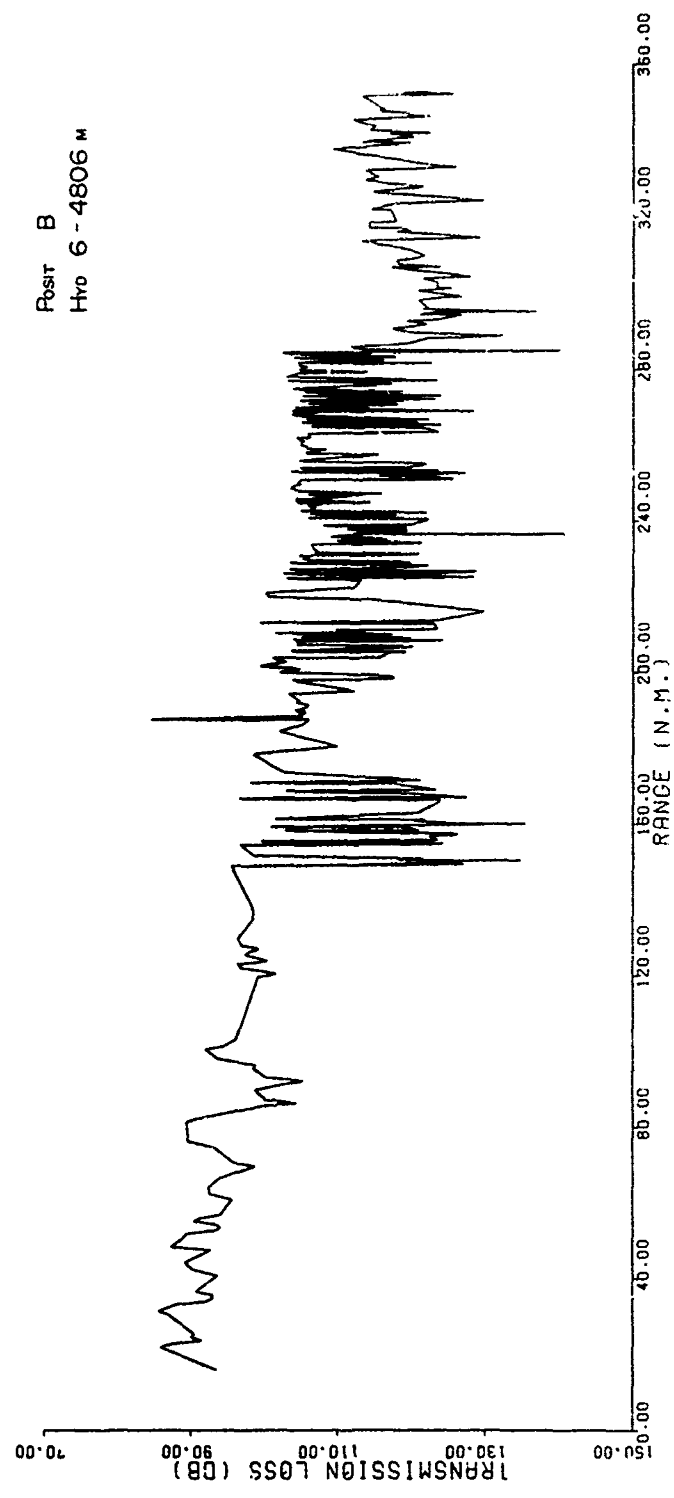
Hyd 5 - 4715 m
RANGE (N.M.)
TRANSMISSION LOSS (DB)


Posit B
Hyd 6 - 4806 m
RANGE (N.M.)
TRANSMISSION LOSS (DB)

APPENDIX B

--

TRANSMISSION LOSS COMPUTED FROM

NORTH SEAL SUS RUN DATA

FROM POSIT C

TO POSIT D

-

RECEIVING SYSTEM ACODAC AT POSIT B

Contents: Pages:

APPENDIX C

TRANSMISSION LOSS COMPUTED FROM

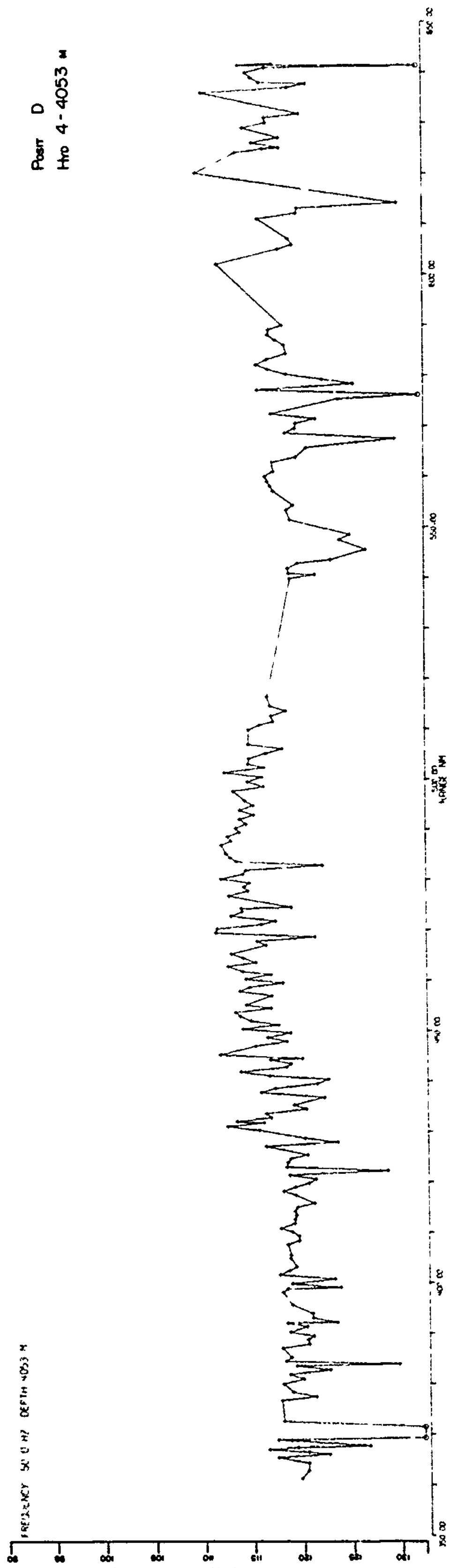
NORTH SEAL SUS RUN DATA

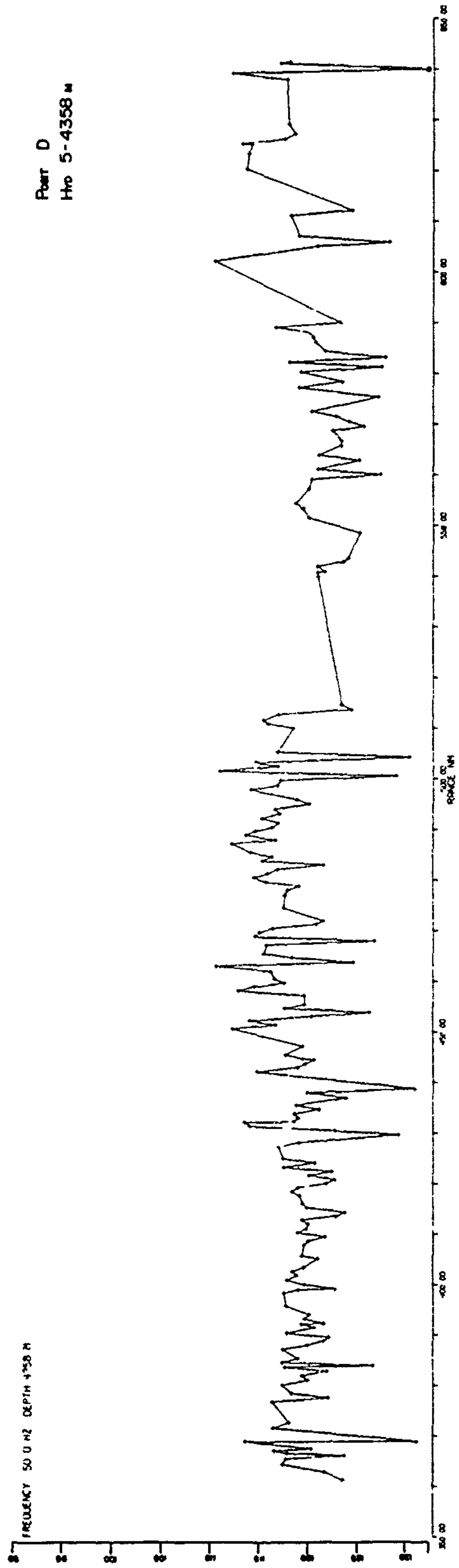
FROM POSIT E

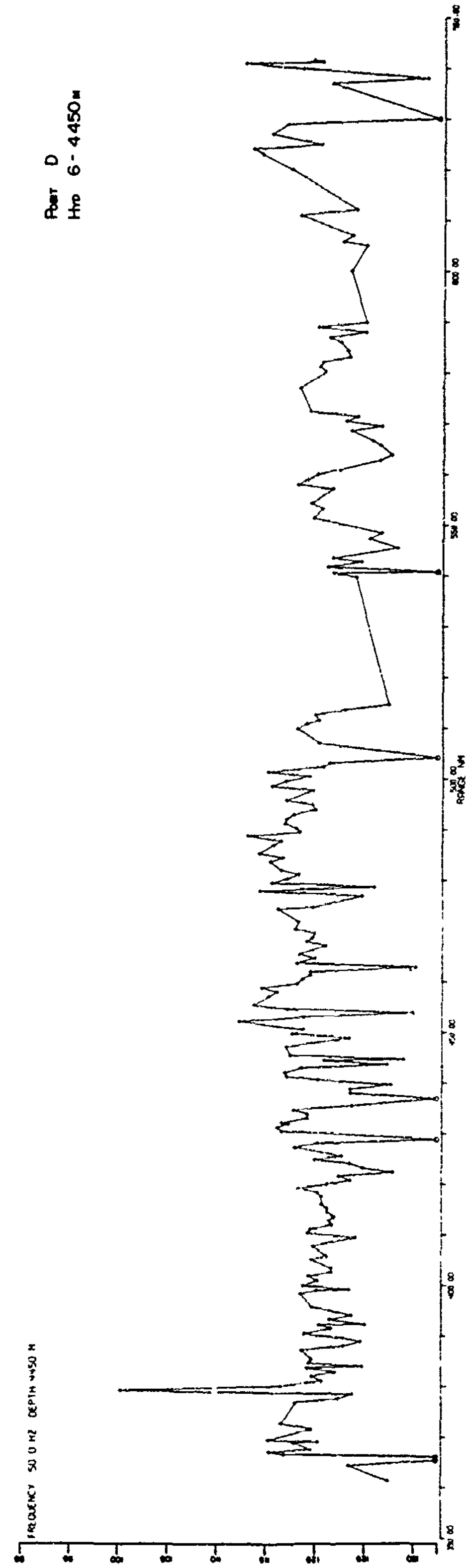
TO POSIT B

RECEIVING SYSTEM ACODAC AT POSIT D

Contents: Pages:


Posit D
Hyd 4-4053 m
FREQUENCY 50.0 HZ DEPTH 4053 M
TRANSMISSION LOSS (DB)
RANGE NM


Port D
Hyd 5-4358 m
FREQUENCY 50.0 HZ DEPTH 4358 M
TRANSMISSION LOSS (DB)
RANGE NM


Port D
Hyd 6-4450 m
FREQUENCY 50.0 HZ DEPTH 4450 M
TRANSMISSION LOSS (DB)
RANGE NM

APPENDIX D

-

TRANSMISSION LOSS COMPUTED FROM

NORTH SEAL SUS RUN DATA

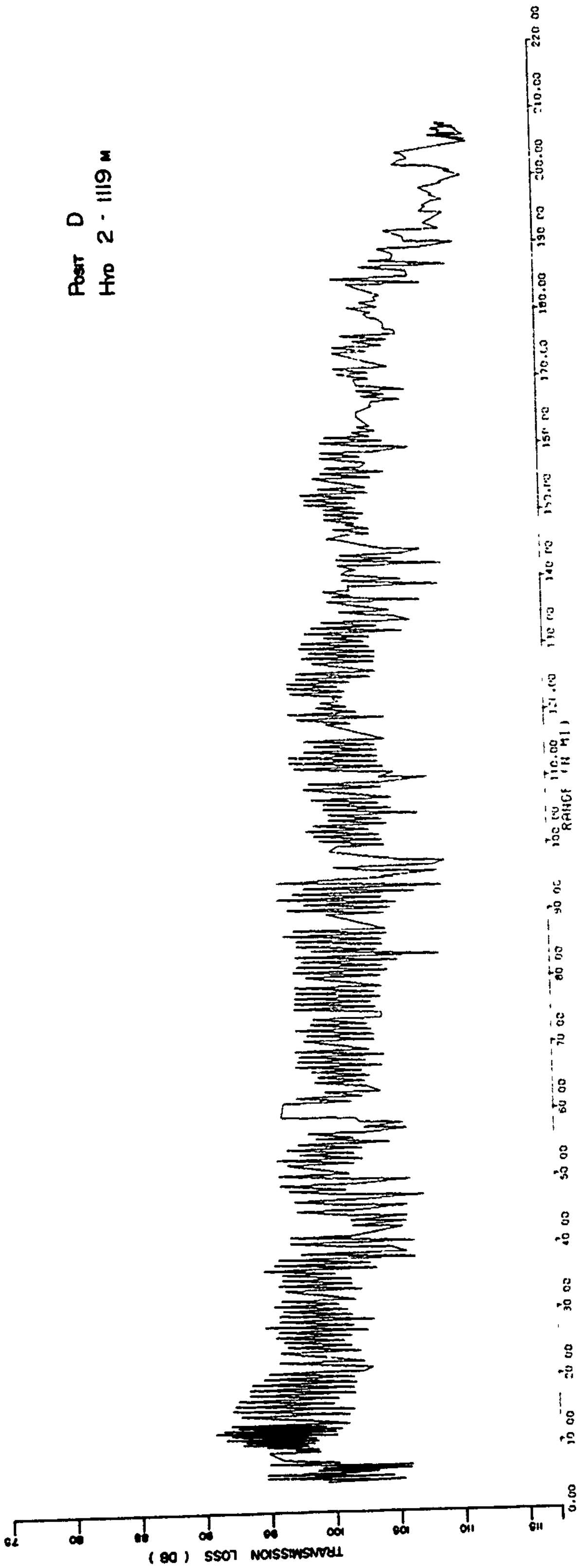
FROM POSIT C

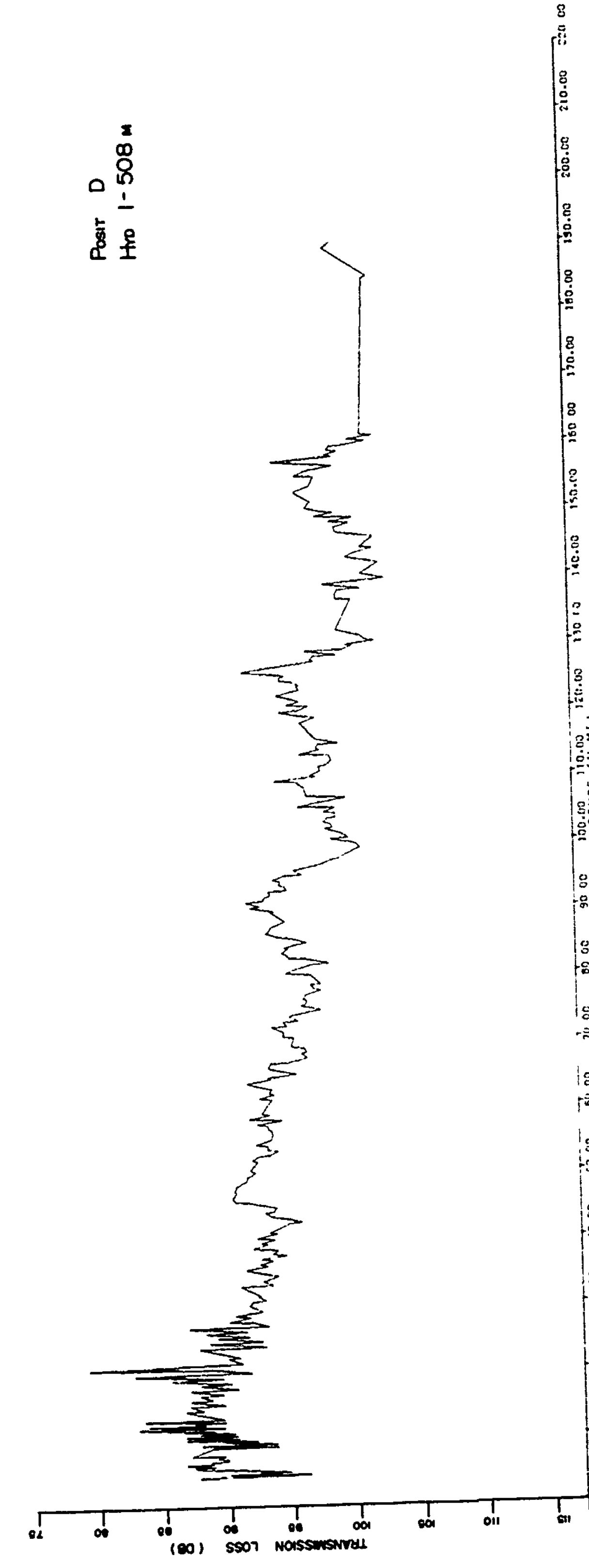
TO POSIT D

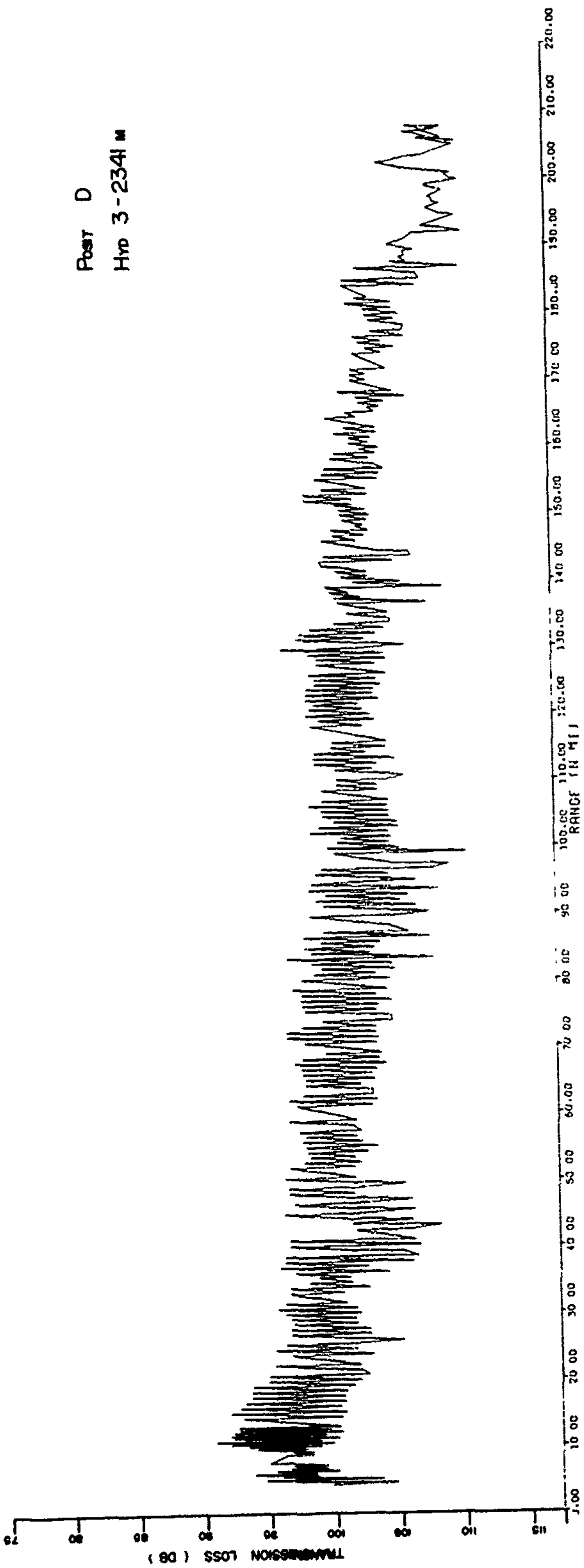
-

RECEIVING SYSTEM ACODAC AT POSIT D

Contents: Pages:


POSIT D
HYD 2 - 1119 M
RANGE (IN MI)
TRANSMISSION LOSS (DB)


POSIT D
HYD 1-508 M
RANGE (IN MI)
TRANSMISSION LOSS (DB)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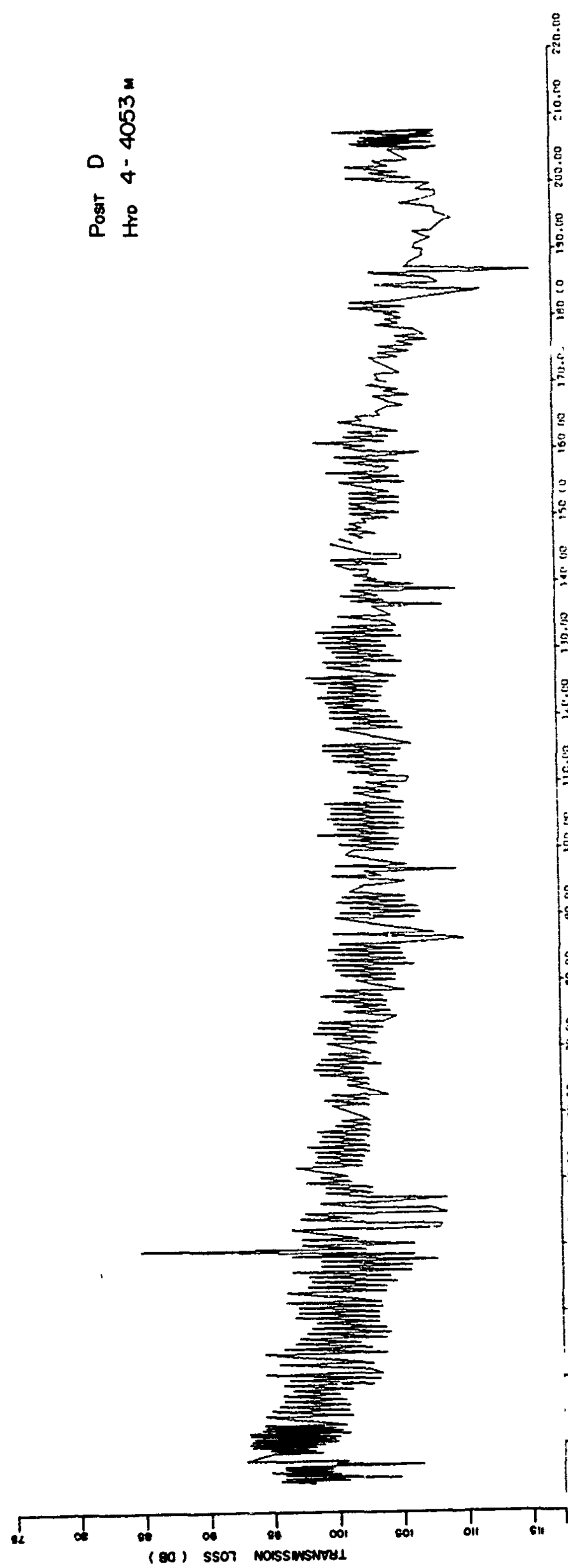
Hyd 3-2341 m
RANGE IN MI
TRANSMISSION LOSS (DB)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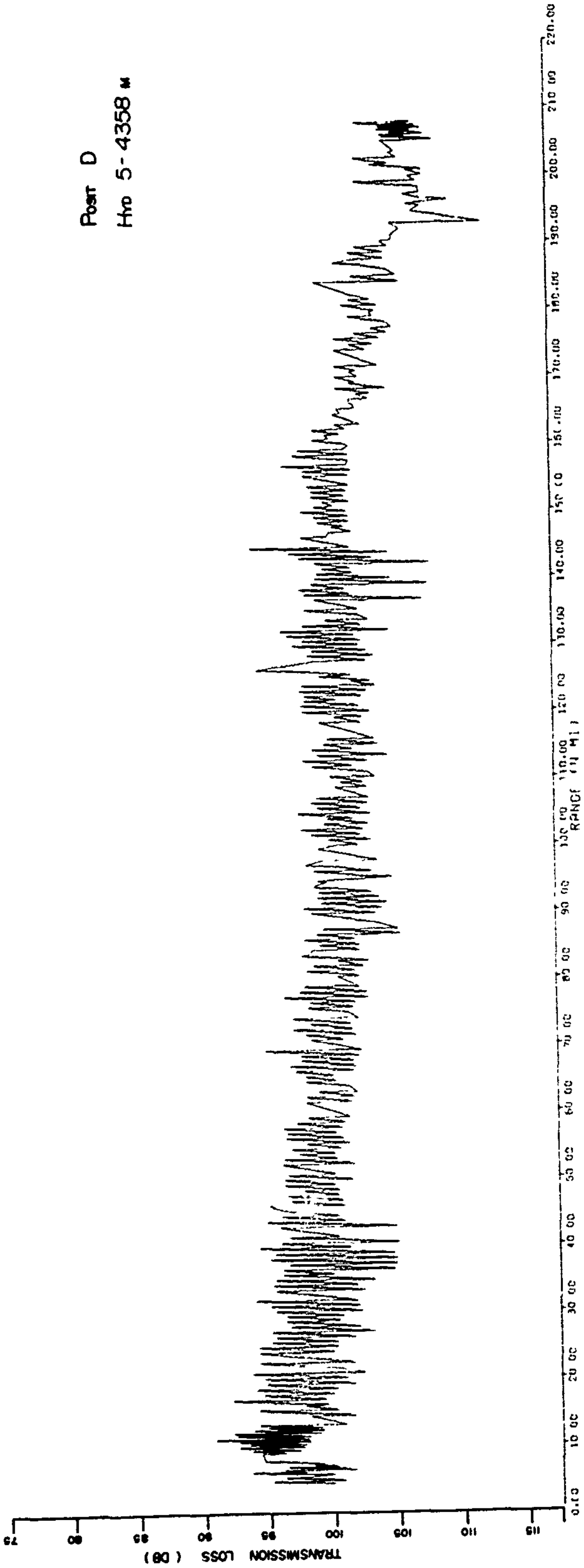
Hyd 4-4053 m
RANGE IN MI
TRANSMISSION LOSS (DB)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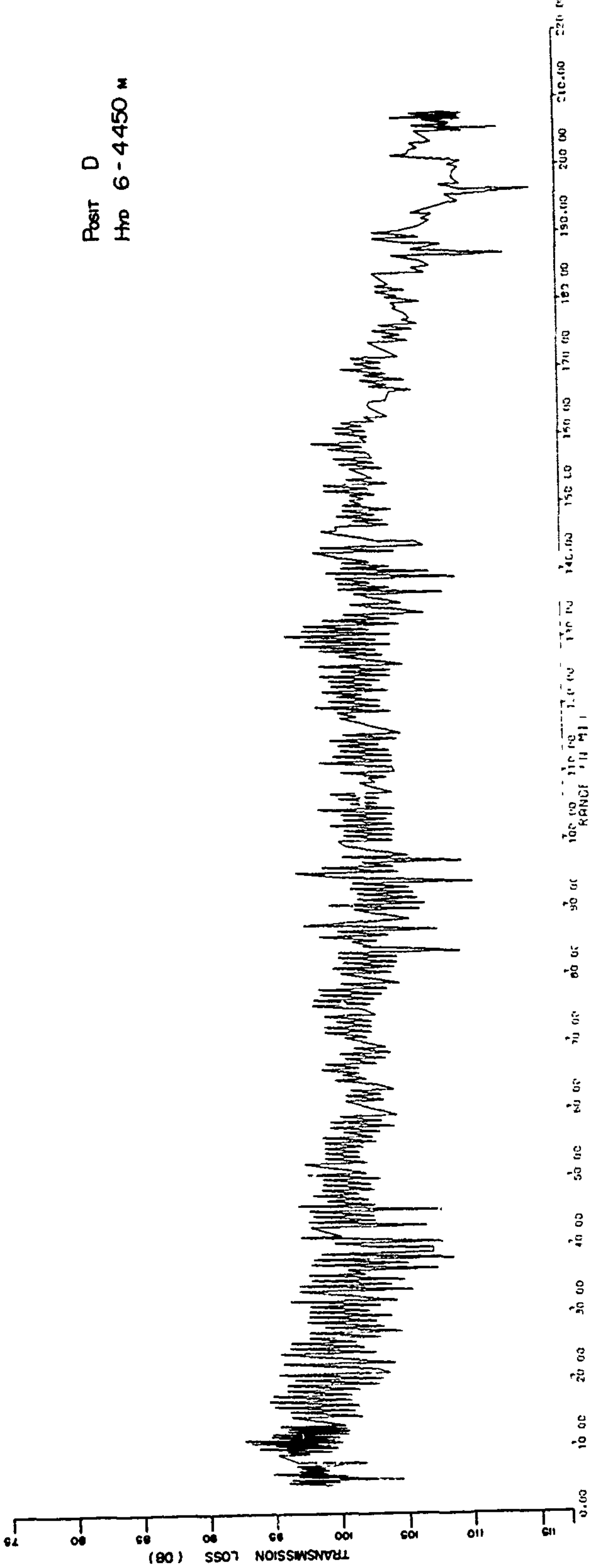
Hyd 5-4358 M
TRANSMISSION LOSS (DB)
RANGE (N MI)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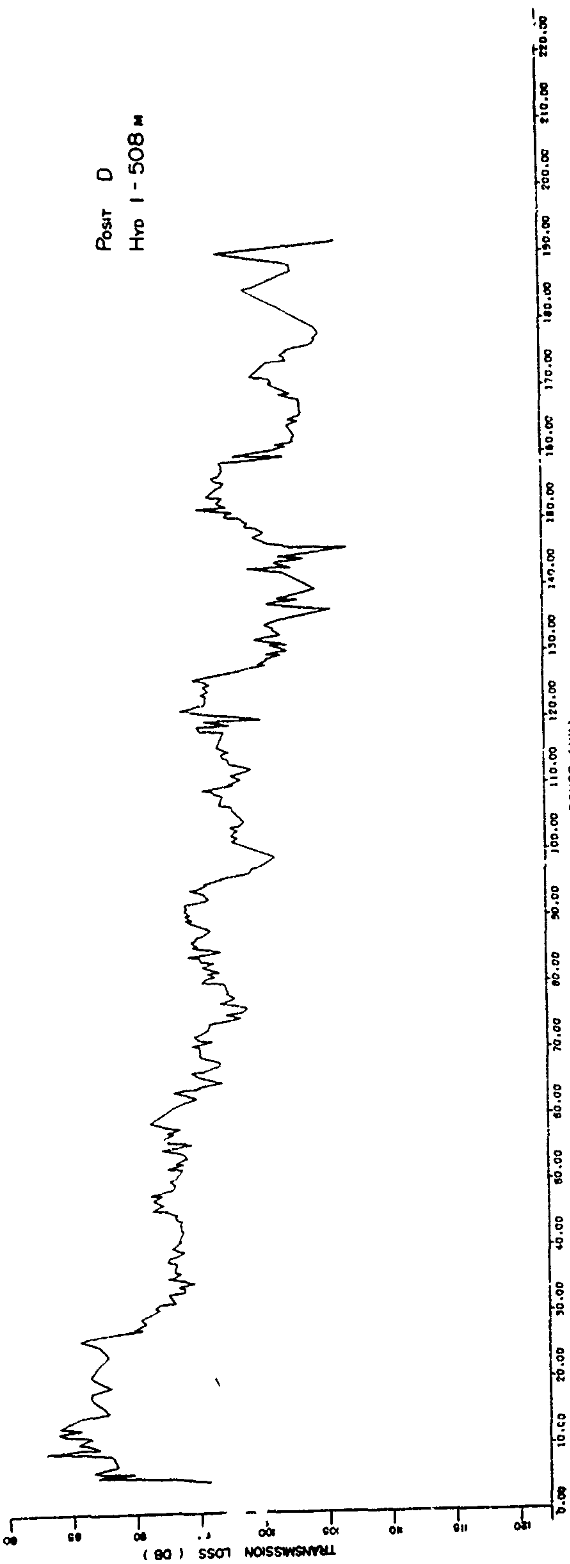
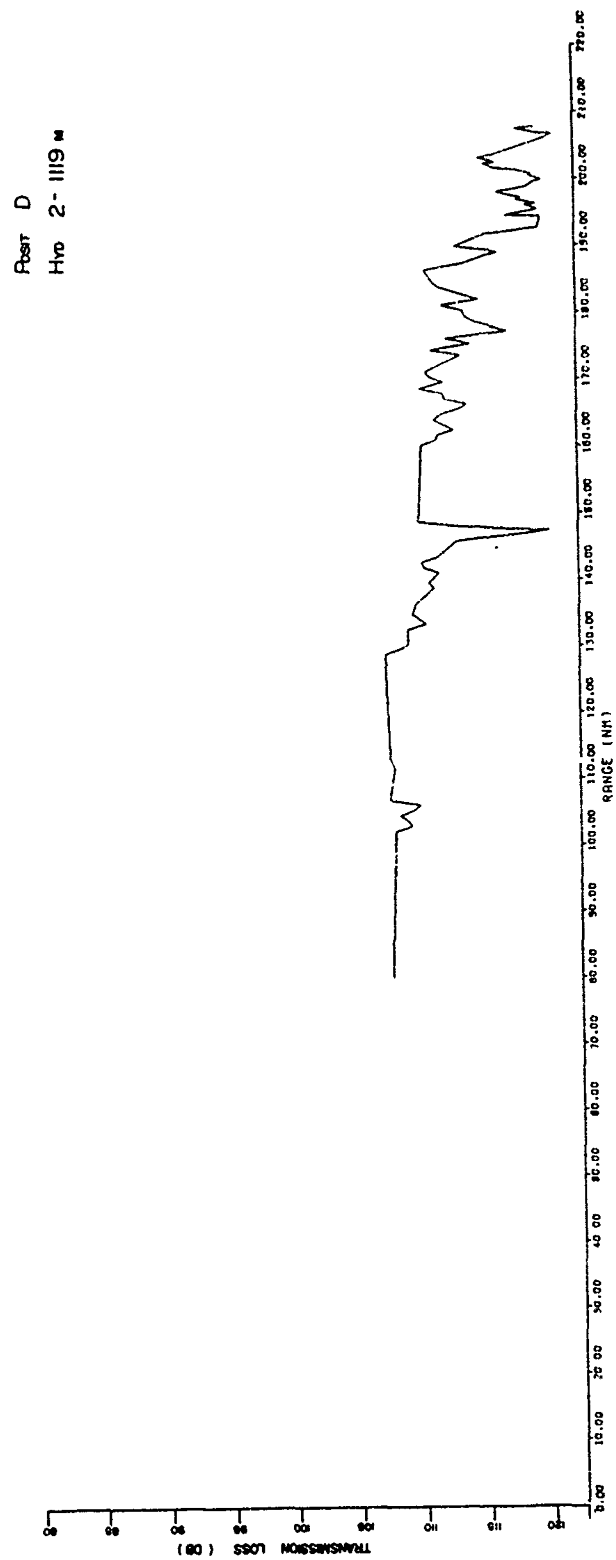
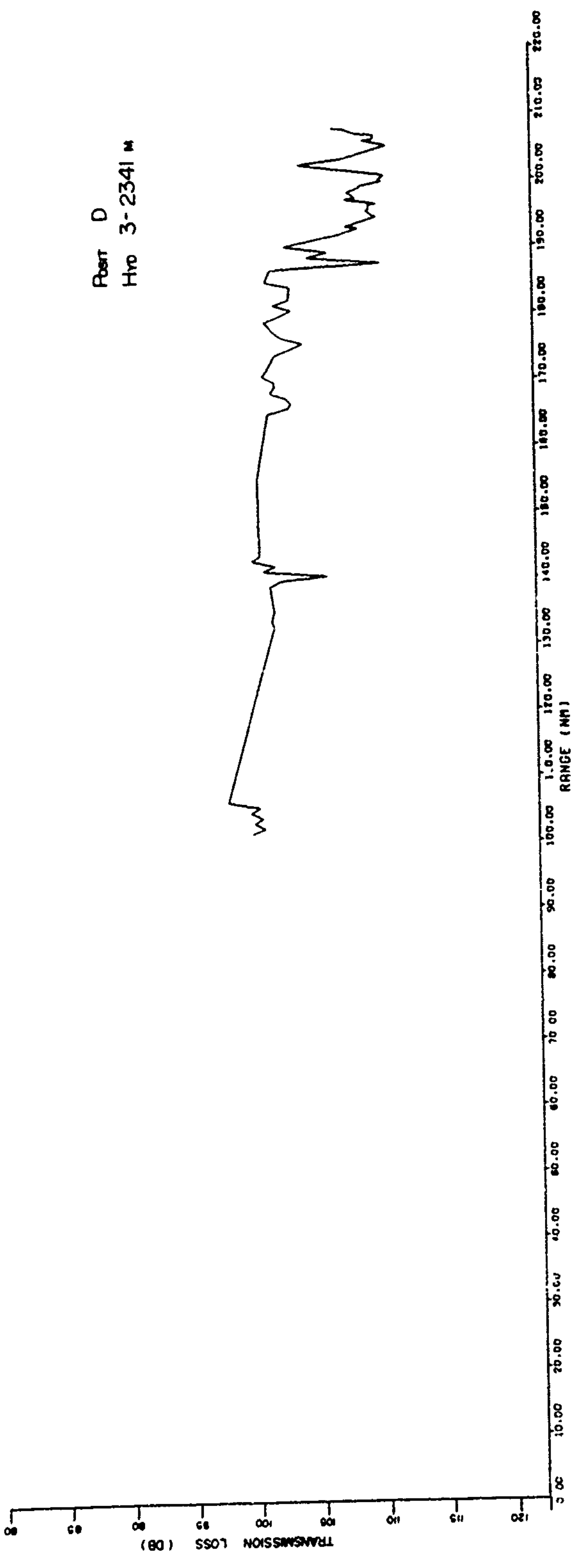
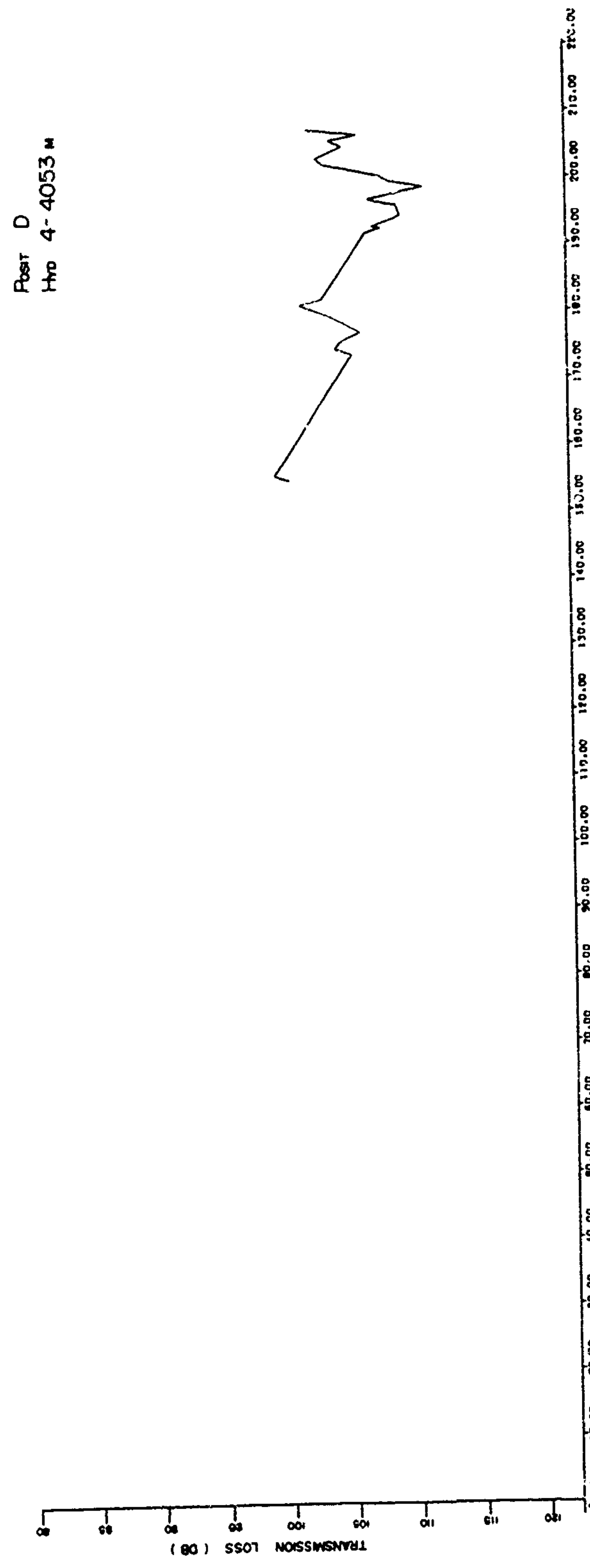
Hyd 6-4450 M
TRANSMISSION LOSS (DB)
RANGE (N MI)


Posit D
Hyd 1-508 m
RANGE (NM)
TRANSMISSION LOSS (DB)


Posit D
Hyd 2-1119 m
RANGE (NM)
TRANSMISSION LOSS (DB)

CONFIDENTIAL





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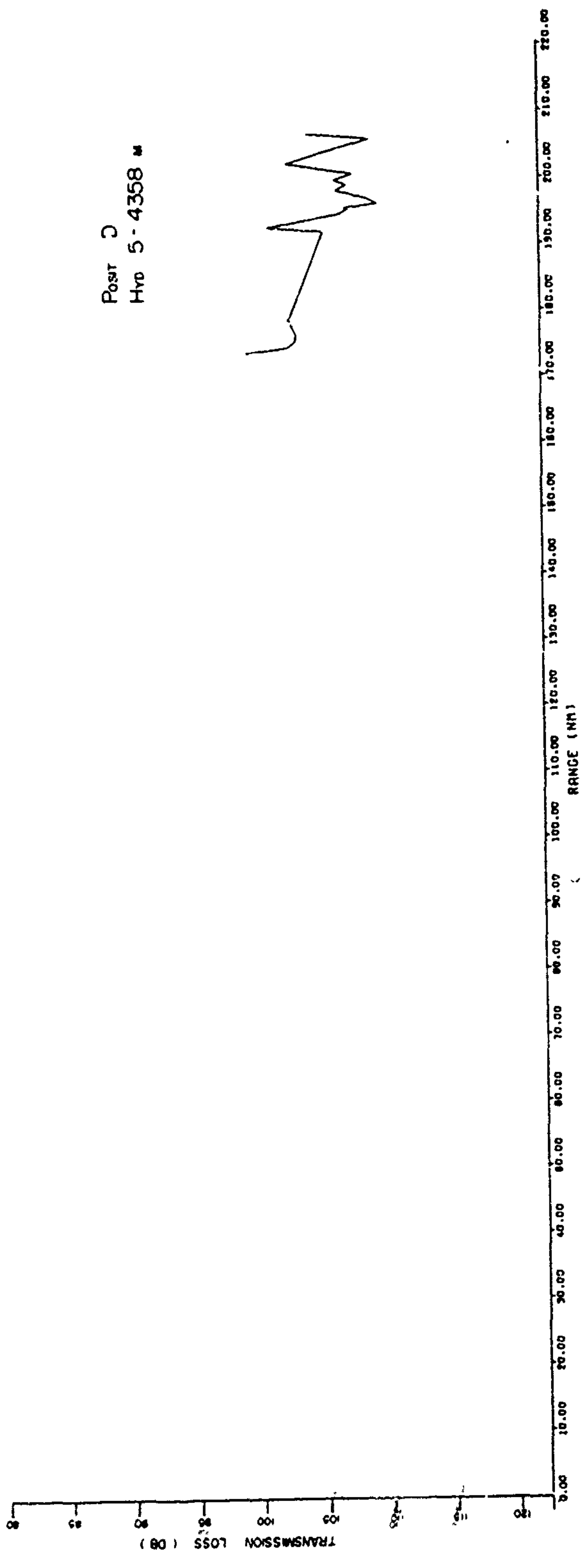
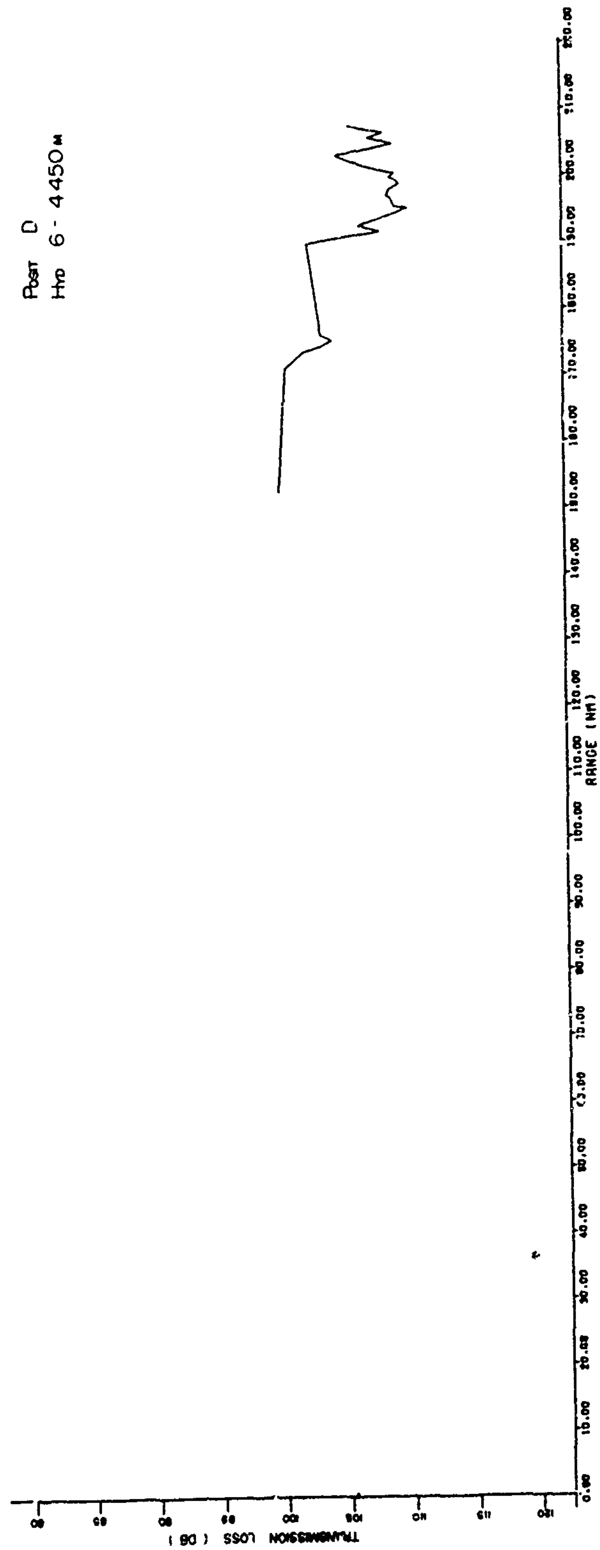
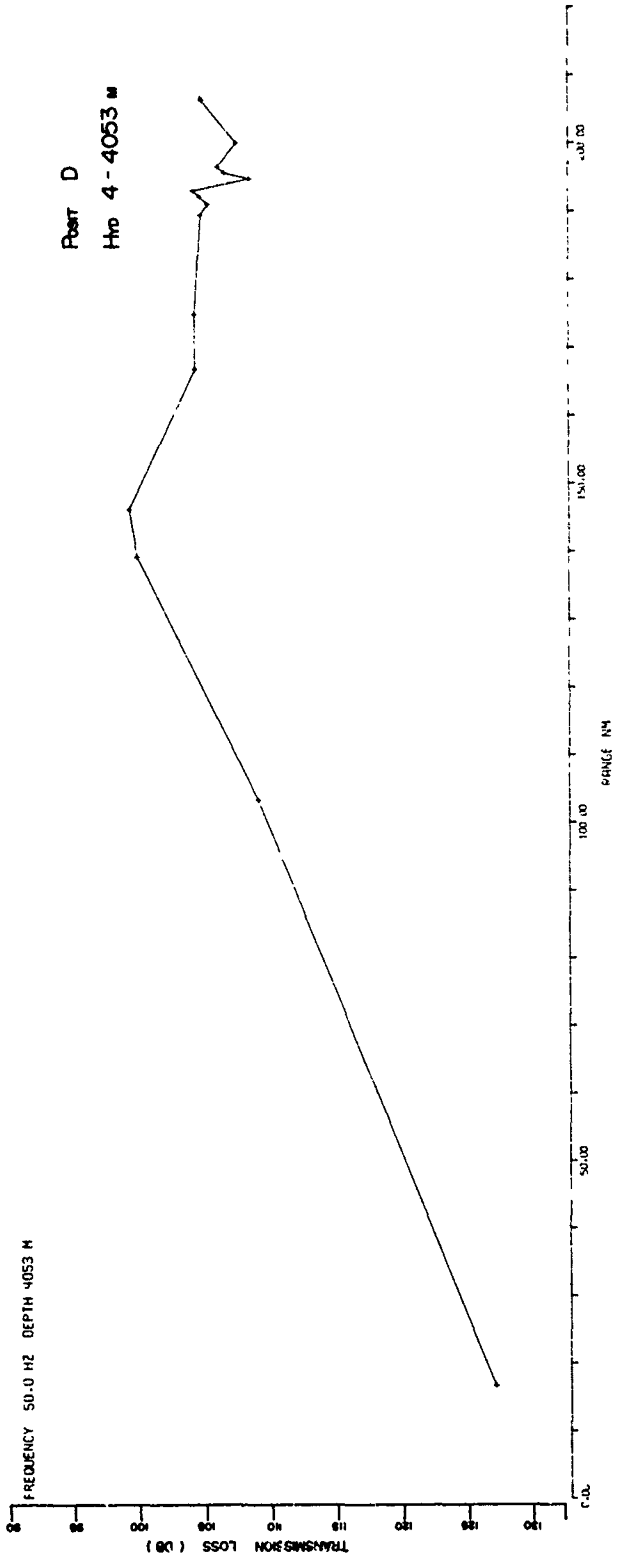
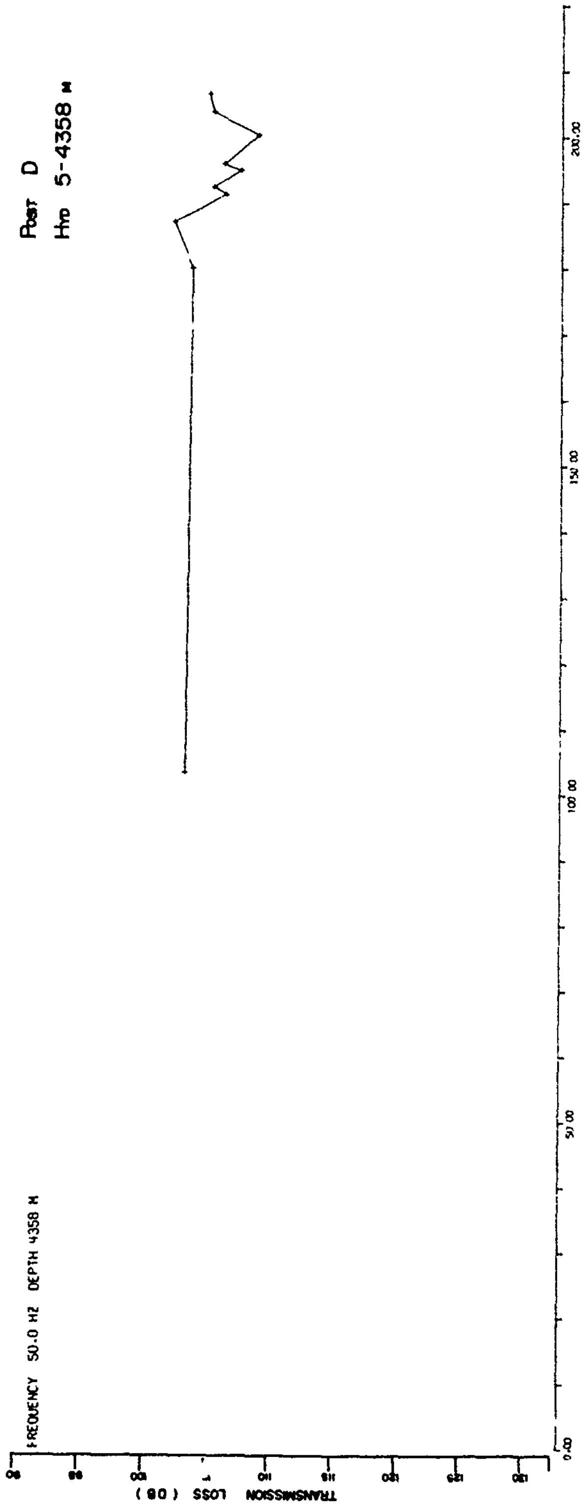
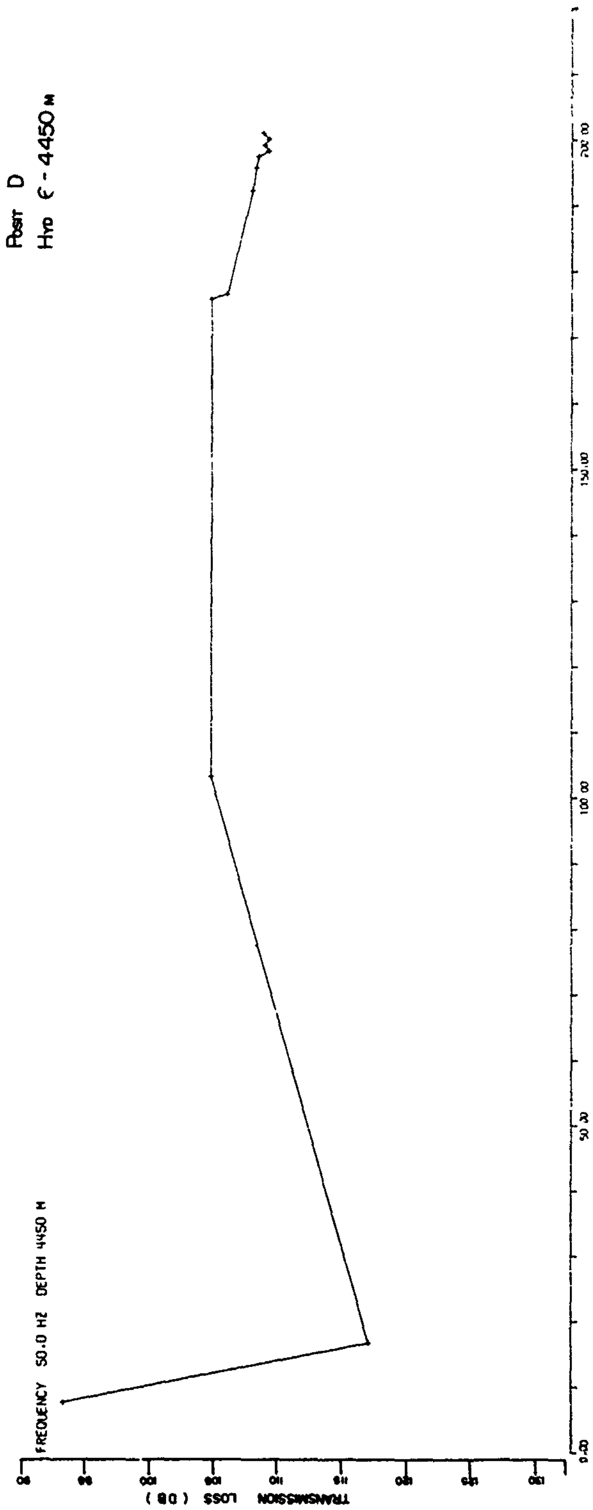

Hyd 5-4358 m
RANGE (NM)
TRANSMISSION LOSS (DB)


Posit D
Hyd 6-4450 m
RANGE (NM)
TRANSMISSION LOSS (DB)


Port D
Hyd 4 - 4053 m
FREQUENCY 50.0 HZ DEPTH 4053 M
TRANSMISSION LOSS (DB)
RANGE NM


Post D
Hyd 5-4358 M
FREQUENCY 50.0 HZ DEPTH 4358 M
RANGE NM
TRANSMISSION LOSS (DB)


Post D
Hyd 6-4450 M
FREQUENCY 50.0 HZ DEPTH 4450 M
RANGE NM
TRANSMISSION LOSS (DB)

APPENDIX E

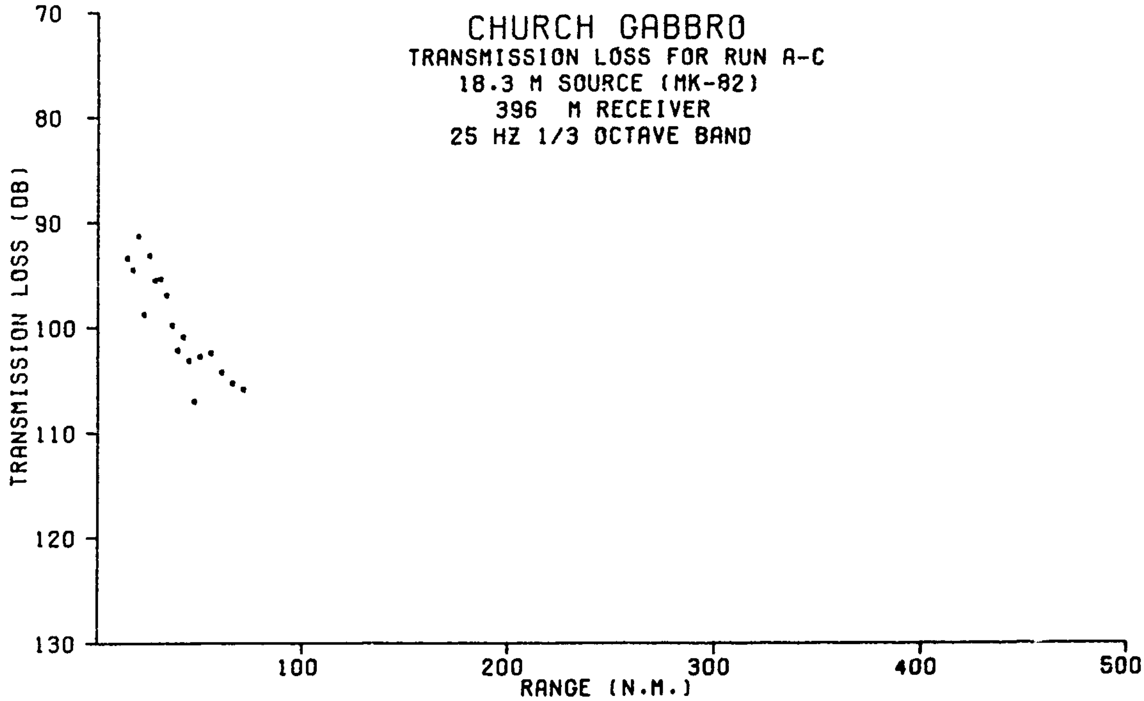
-

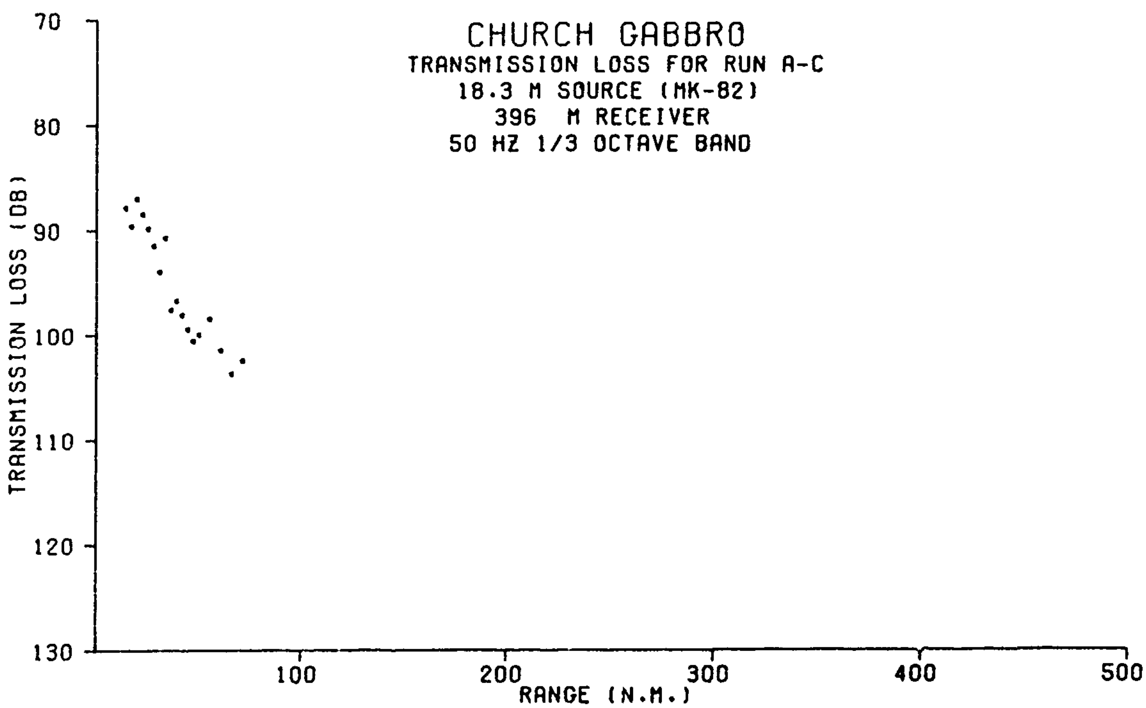
TRANSMISSION LOSS COMPUTED FROM
AIRCRAFT SUS RUN DATA
FROM POSIT A
TO POSIT C

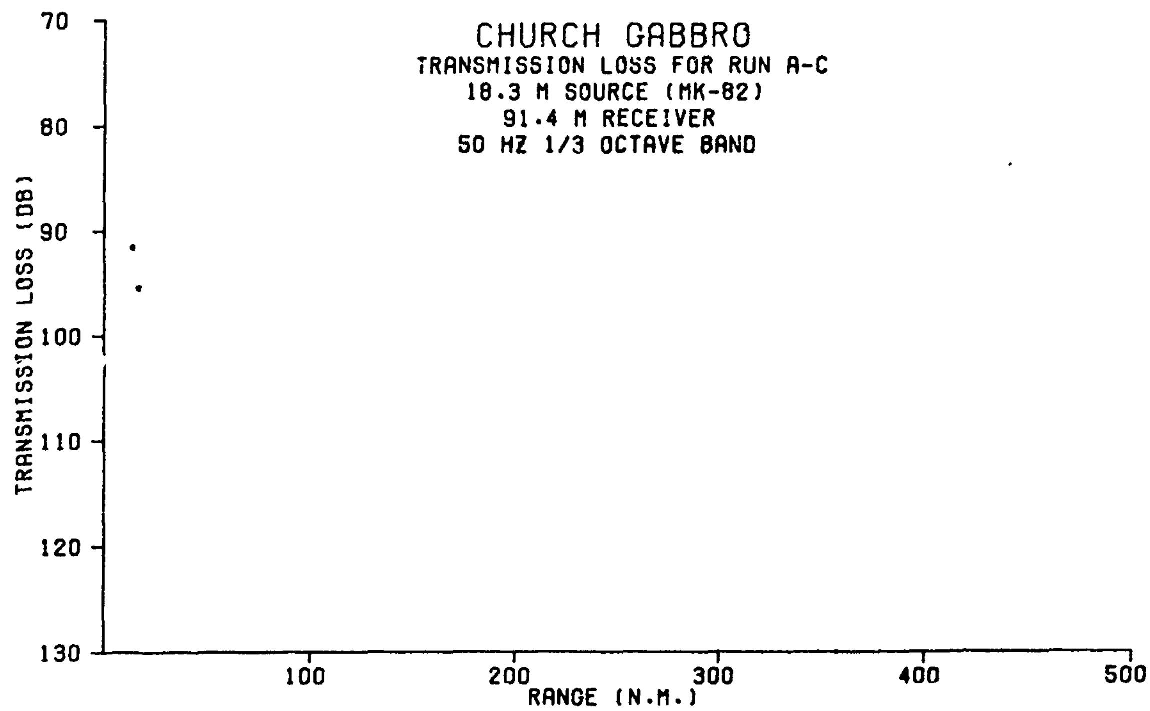
-

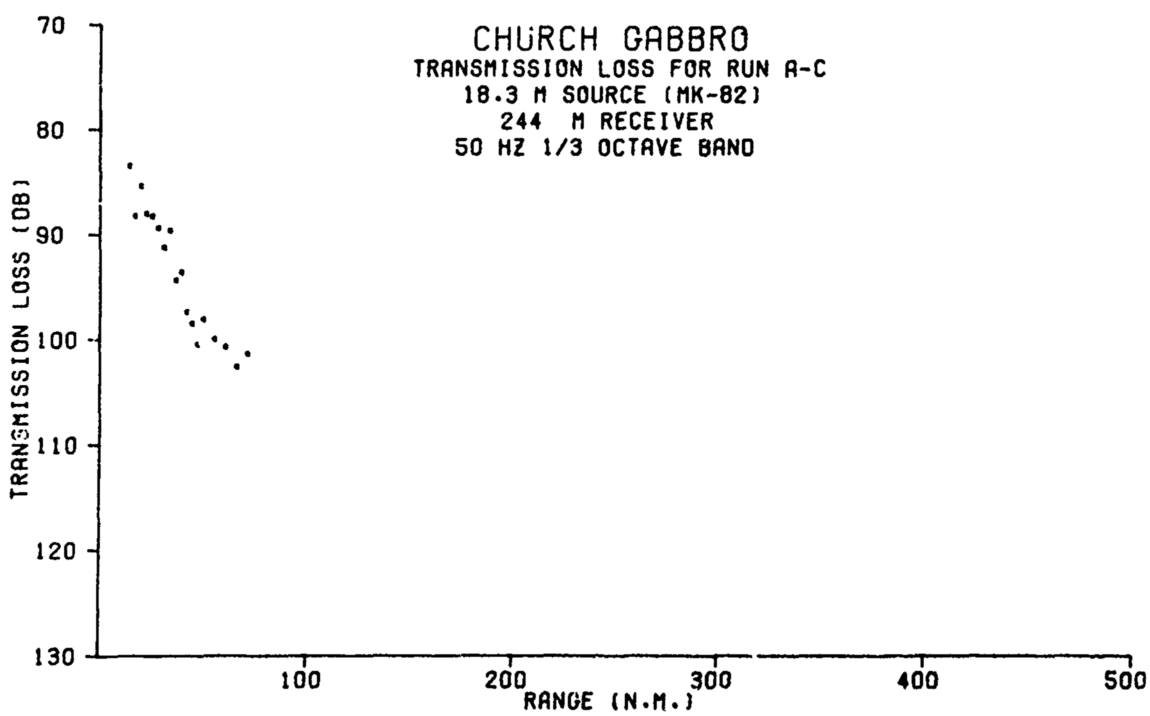
RECEIVING SYSTEMS TABS AND SONOBUOYS AT POSIT C

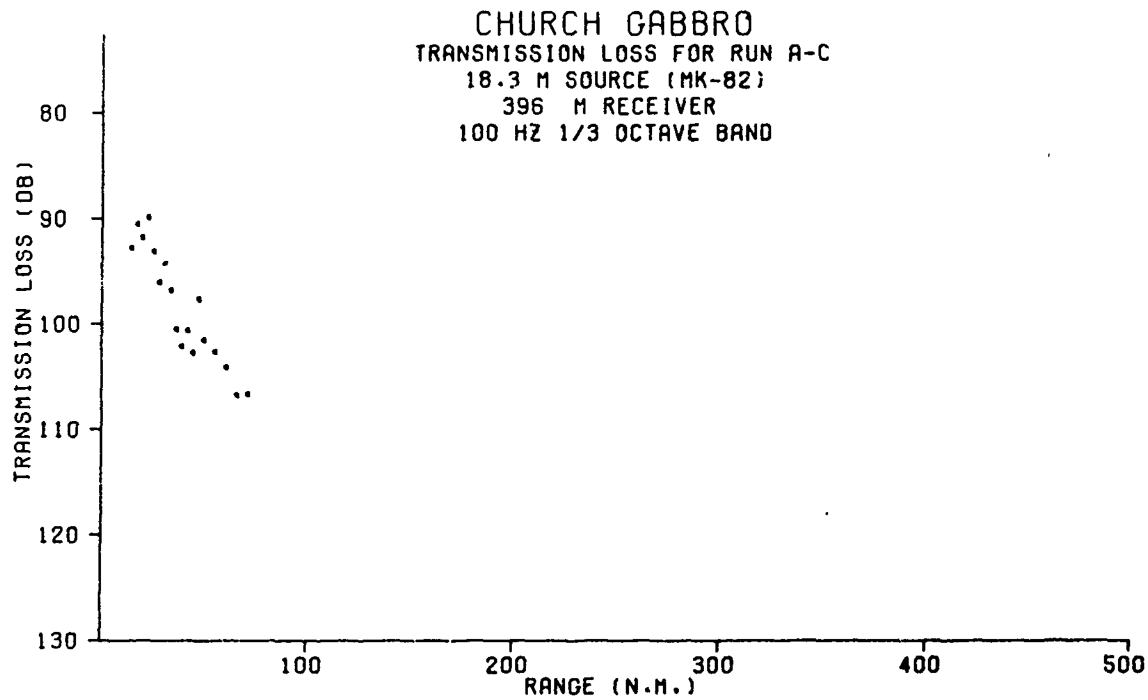
(Computations by Naval Underwater Systems Center, New London Laboratory)

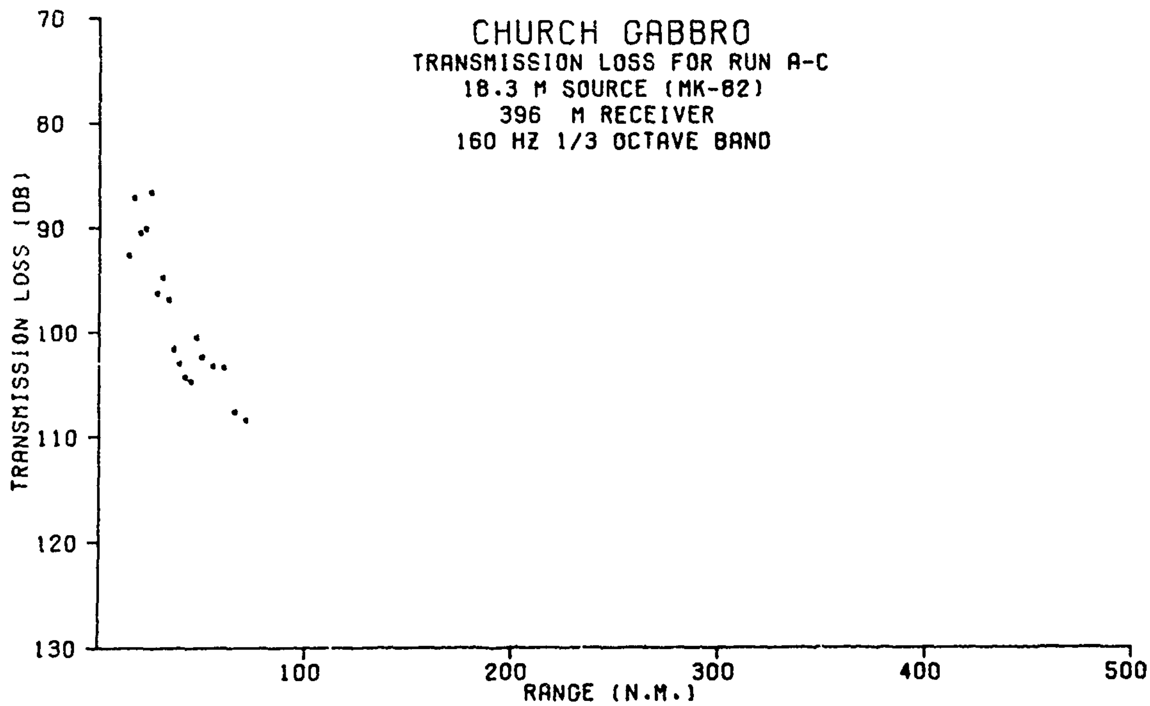

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
396 M RECEIVER
25 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

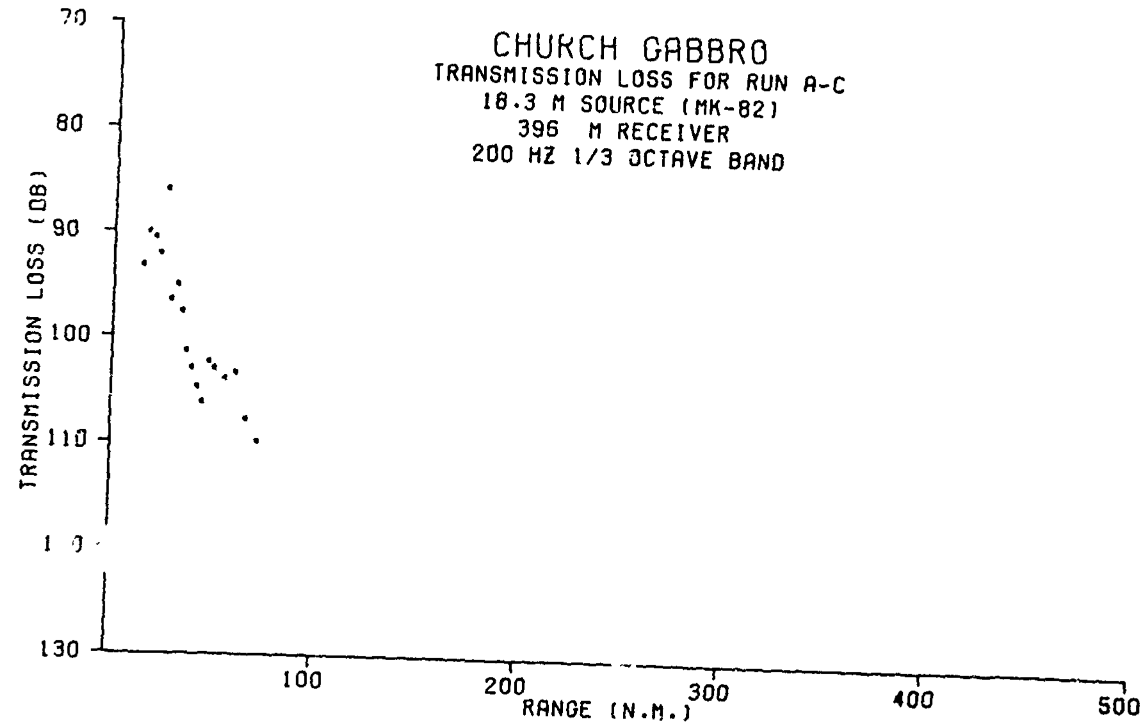

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
396 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

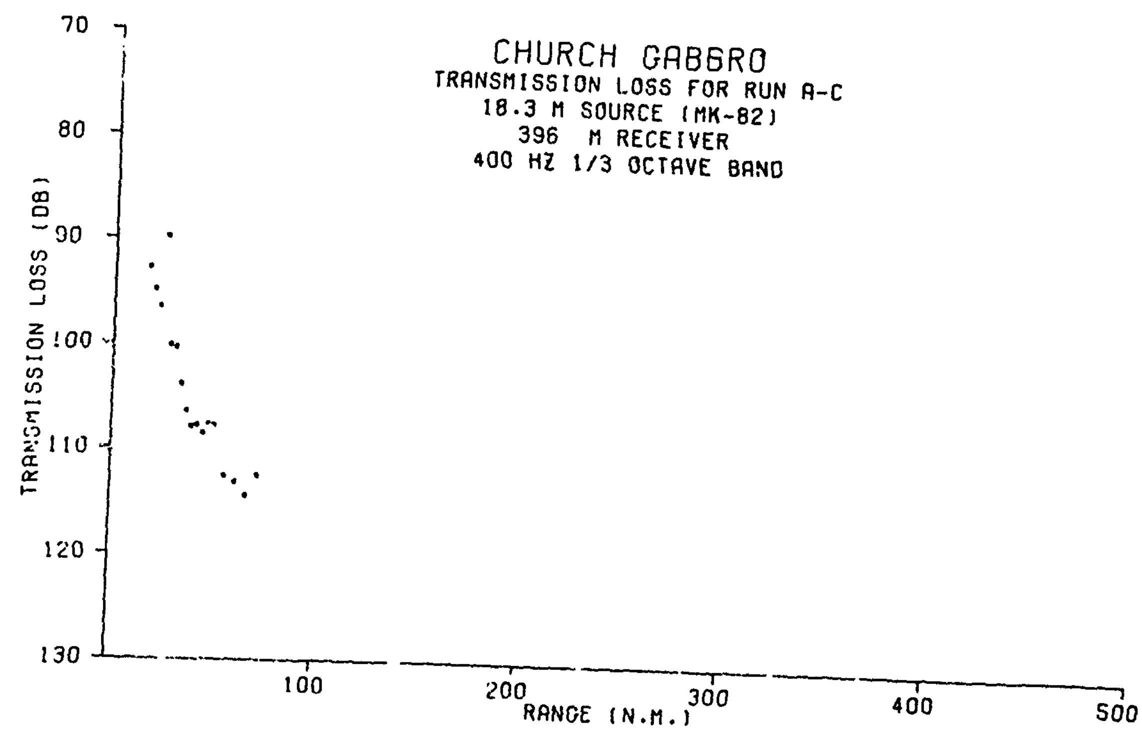

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
91.4 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
RANGE (N.M.)
100
200
300
400
500


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
244 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
RANGE (N.M.)
100
200
300
400
500

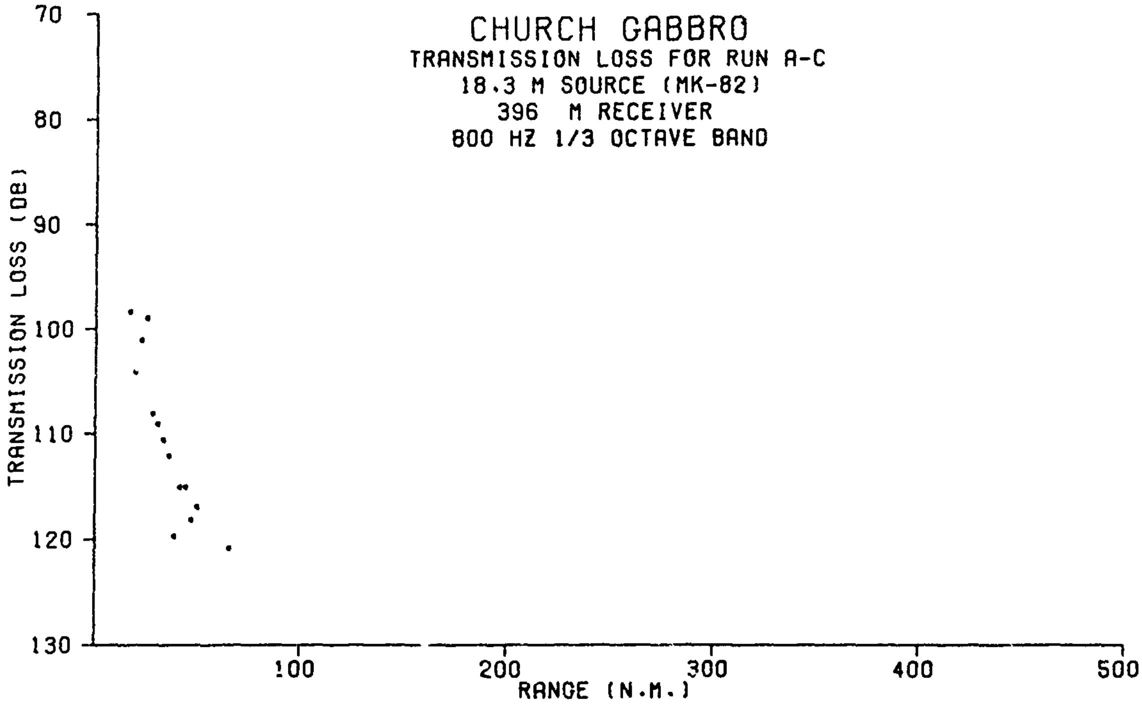

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
396 M RECEIVER
100 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
396 M RECEIVER
160 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
396 M RECEIVER
200 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN A-C
18.3 M SOURCE (MK-82)
396 M RECEIVER
400 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

CONFIDENTIAL



APPENDIX F

-

TRANSMISSION LOSS COMPUTED FROM

AIRCRAFT SUS RUN DATA

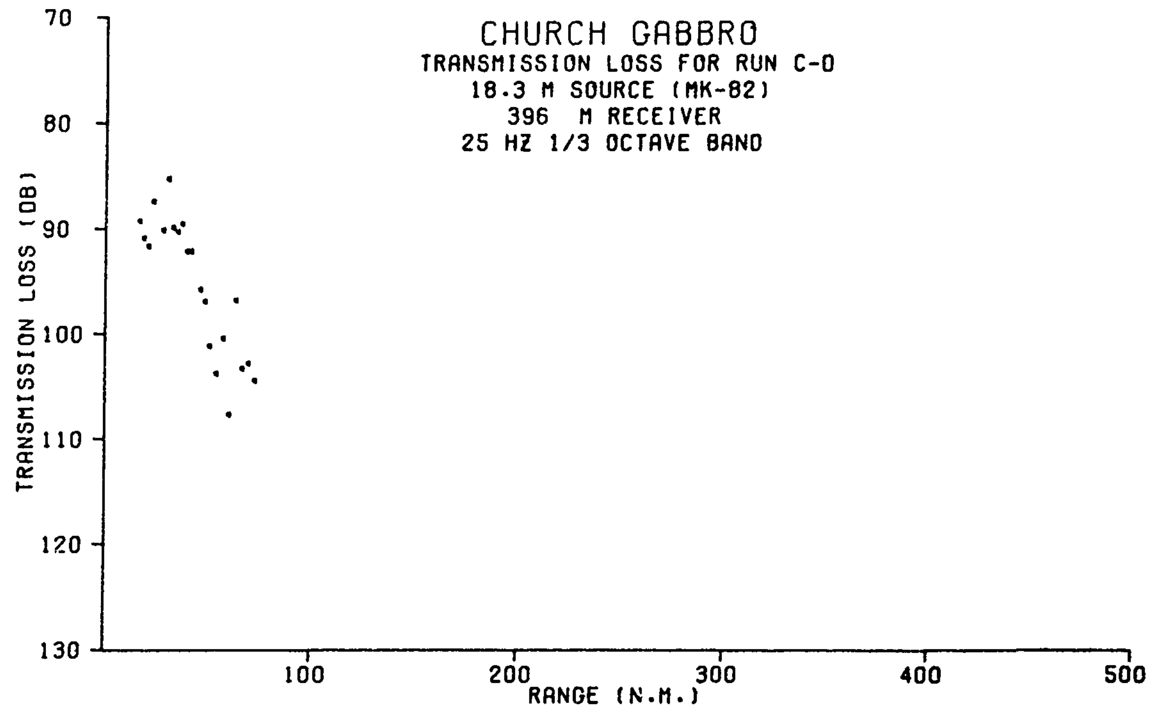
FROM POSIT C

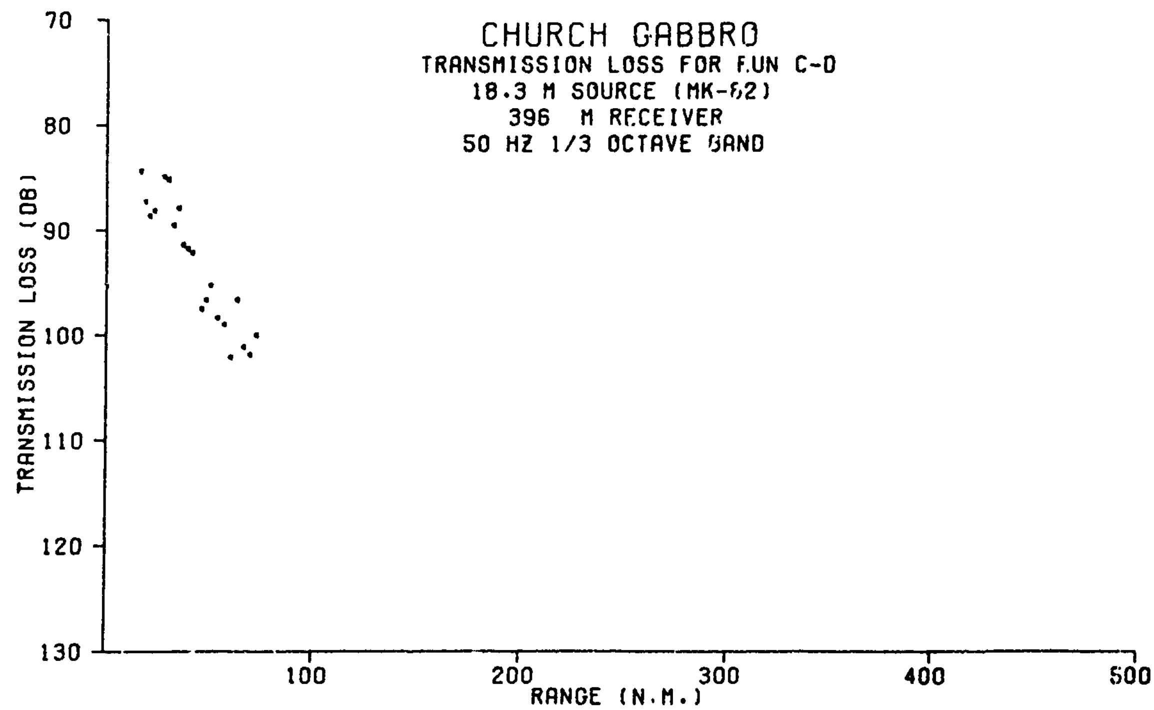
TO POSIT D

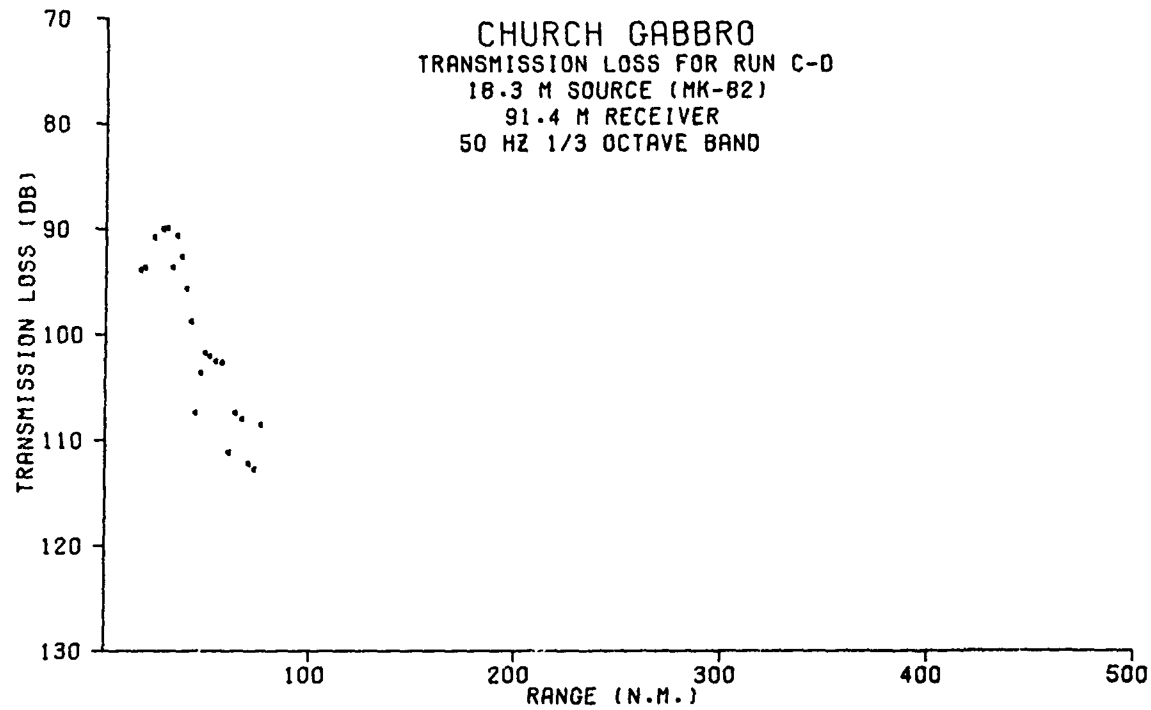
-

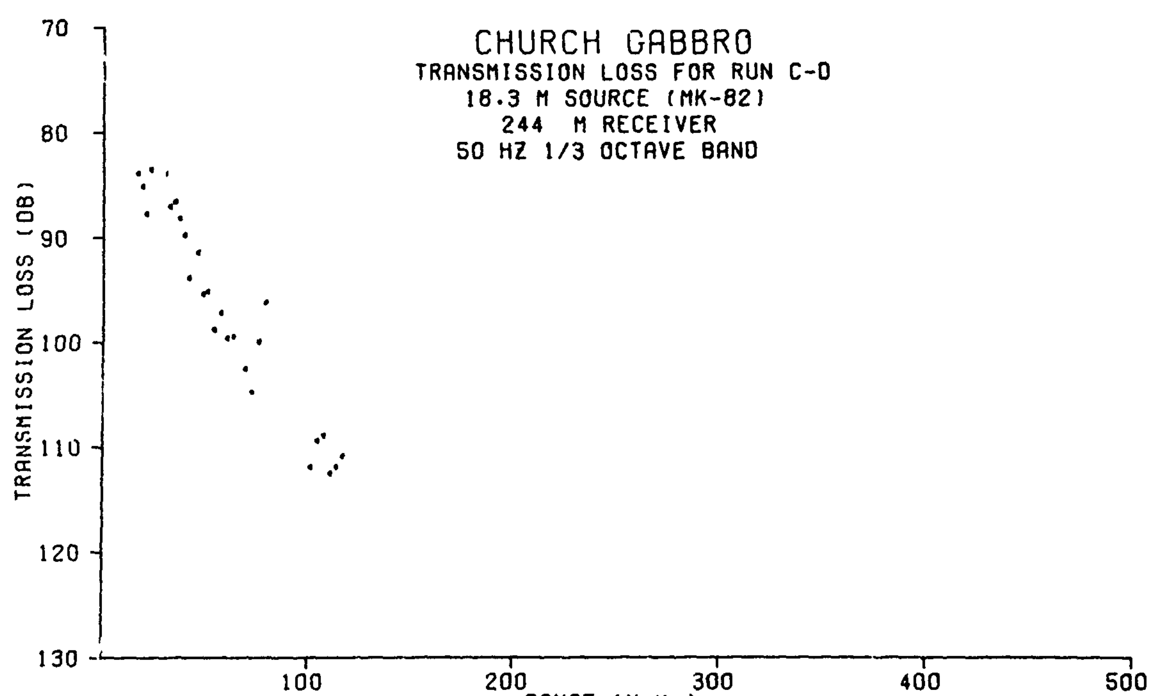
RECEIVING SYSTEMS TABS AND SONOBUOYS AT POSIT C

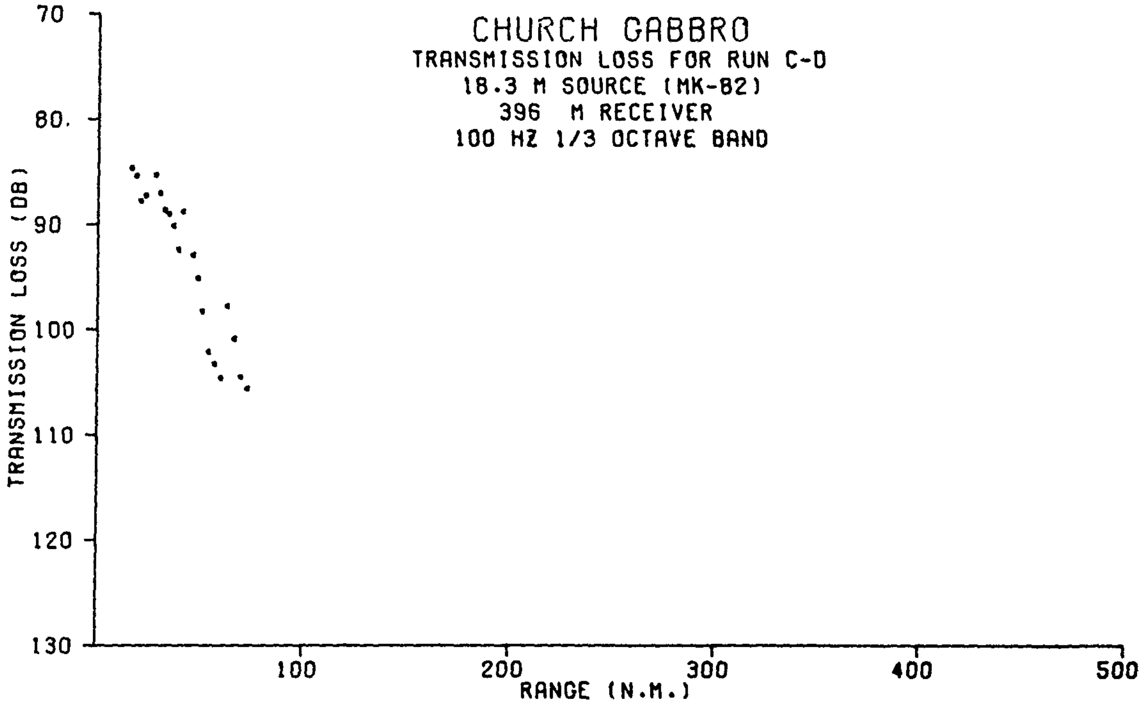
(Computations by Naval Underwater Systems Center, New London Laboratory)

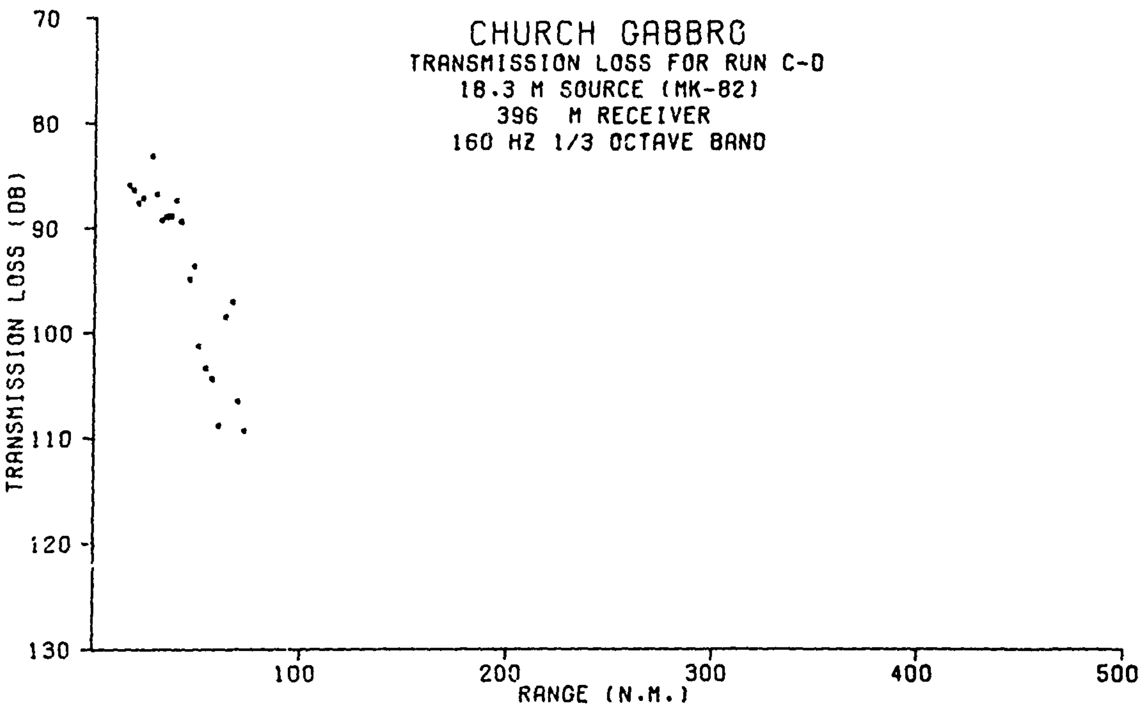

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
25 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

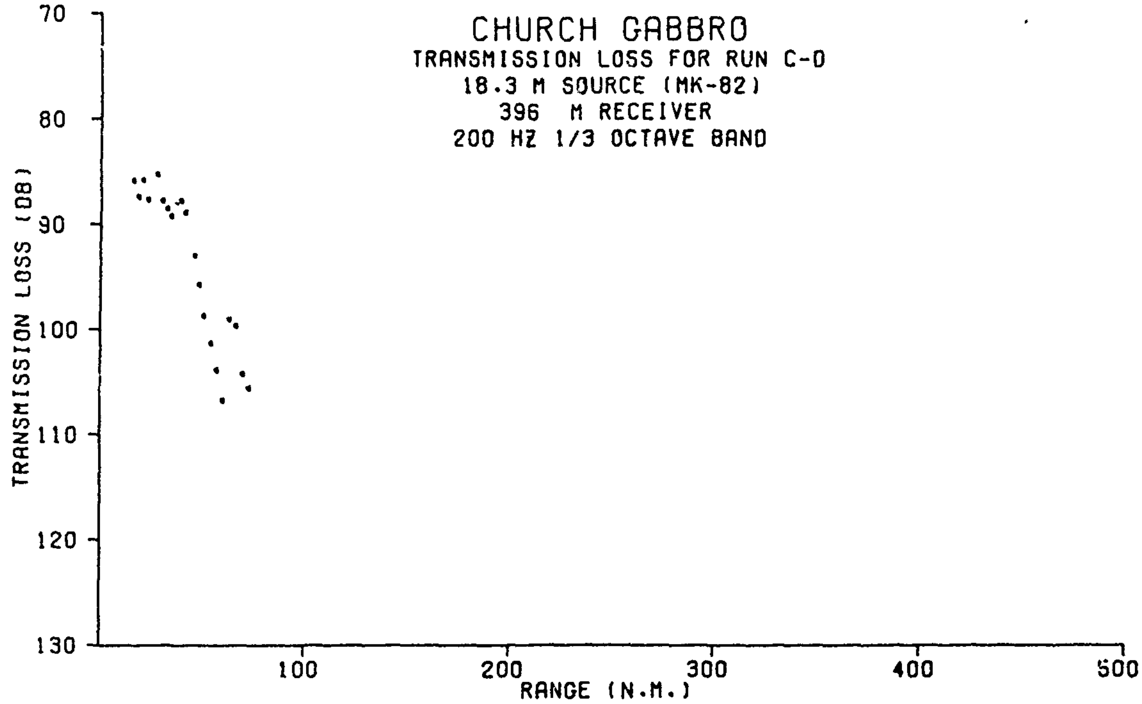

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
91.4 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

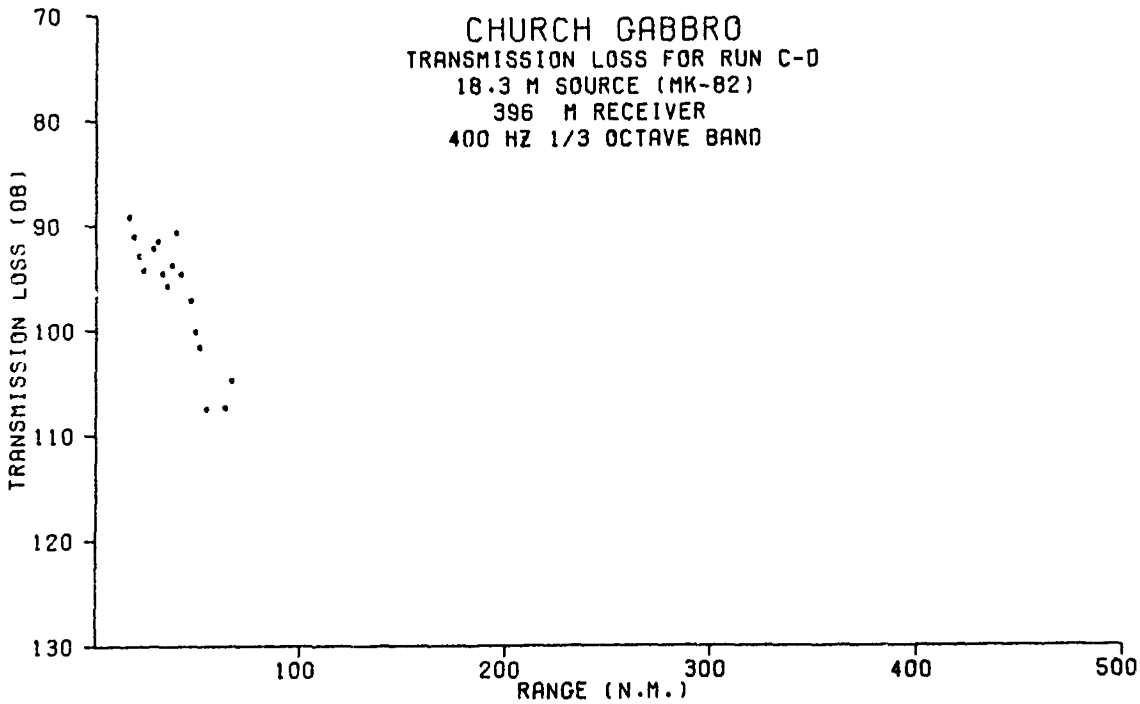

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
244 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

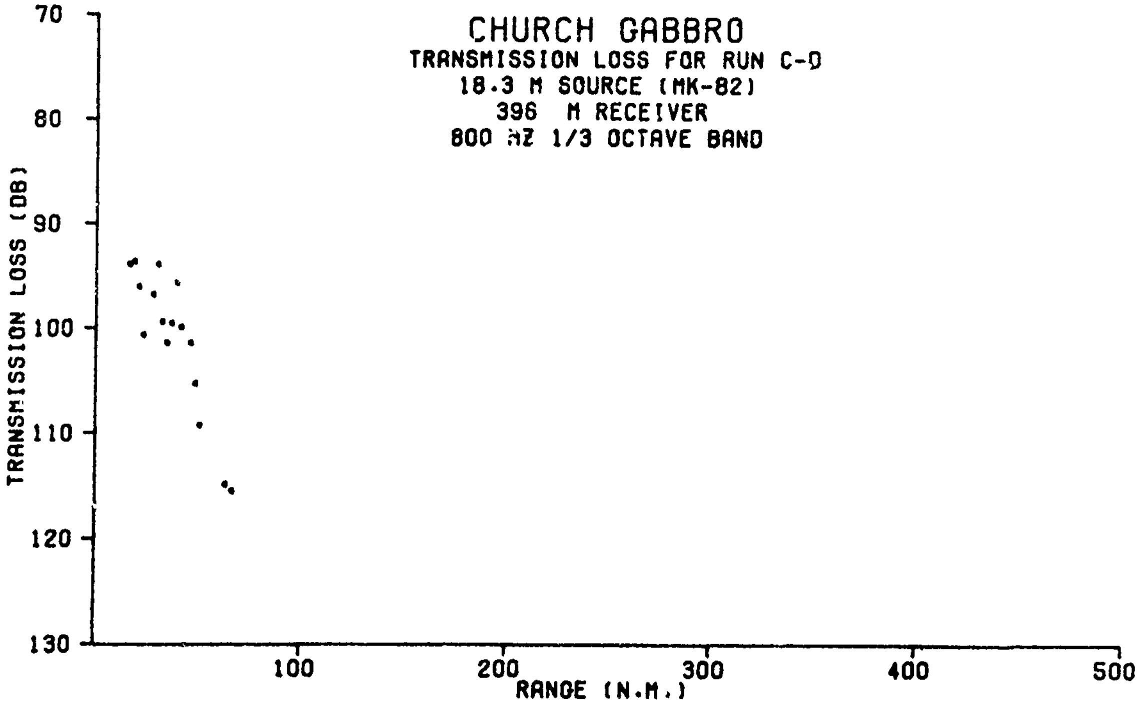

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
100 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
160 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
200 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

F7


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
400 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-D
18.3 M SOURCE (MK-82)
396 M RECEIVER
800 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

APPENDIX G

-

TRANSMISSION LOSS COMPUTED FROM

AIRCRAFT SUS RUN DATA

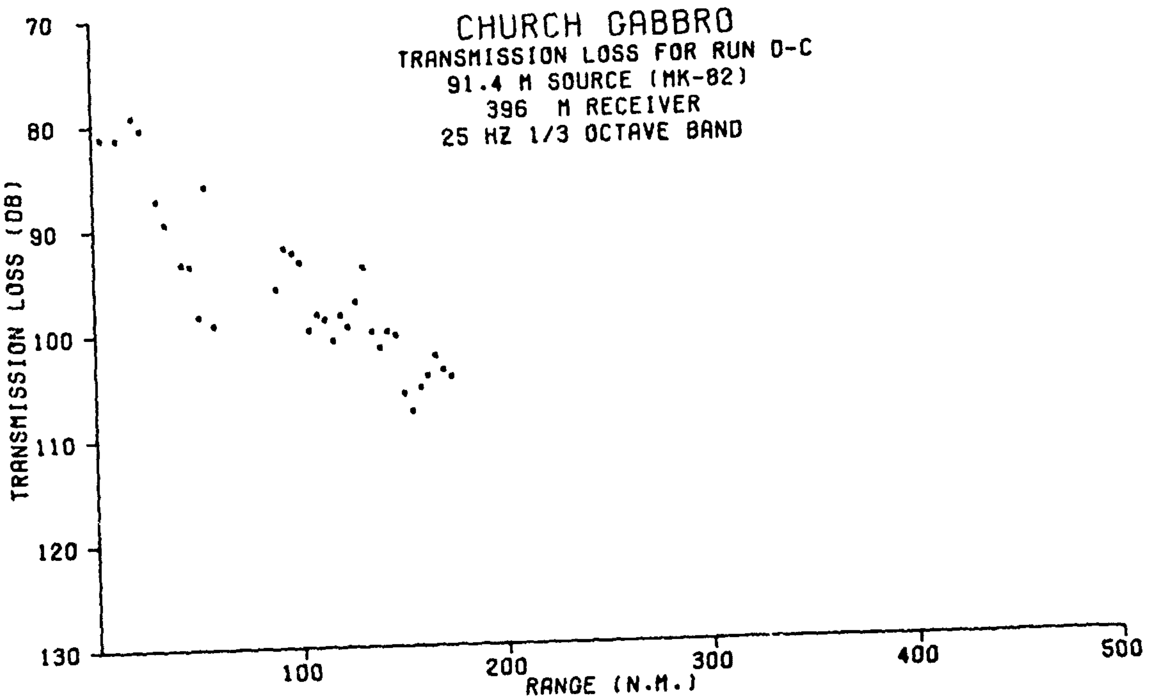
FROM POSIT D

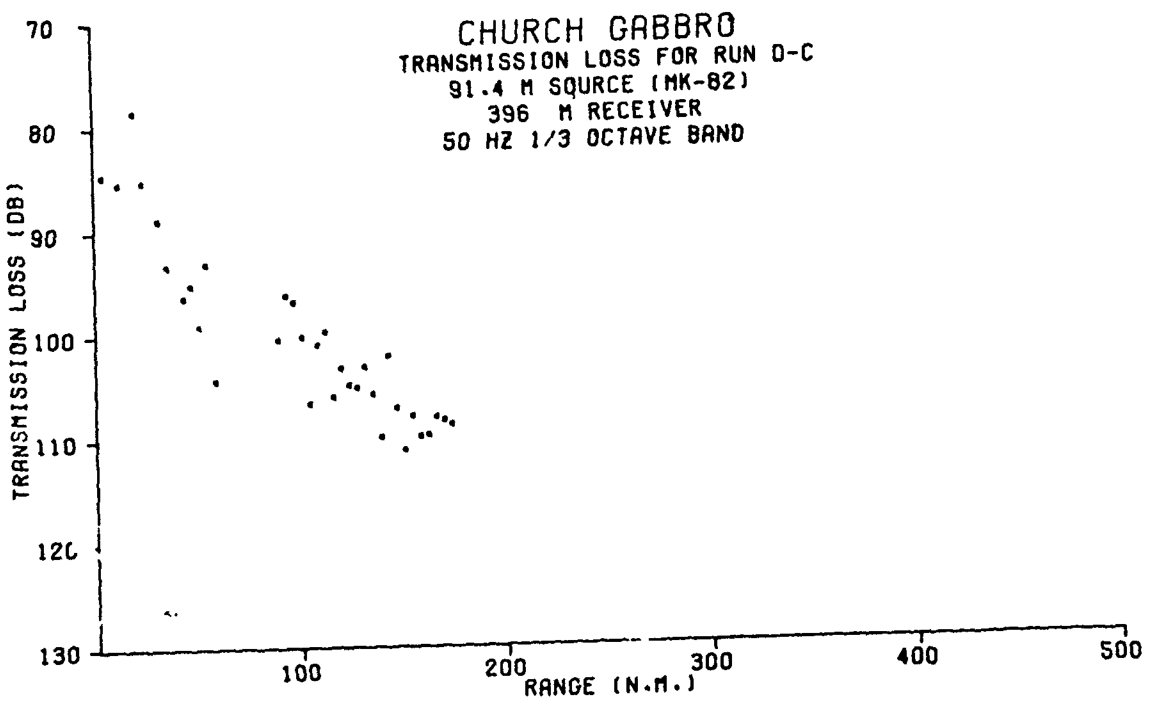
TO POSIT C

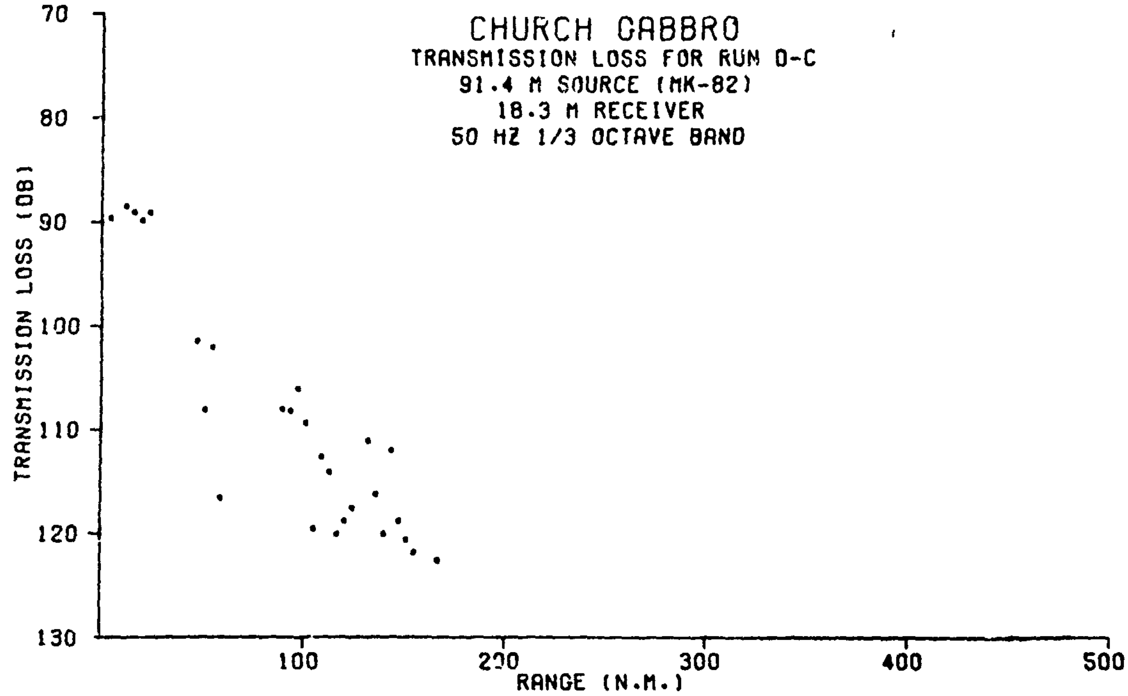
-

RECEIVING SYSTEMS TABS AND SONOBUOYS AT POSIT C

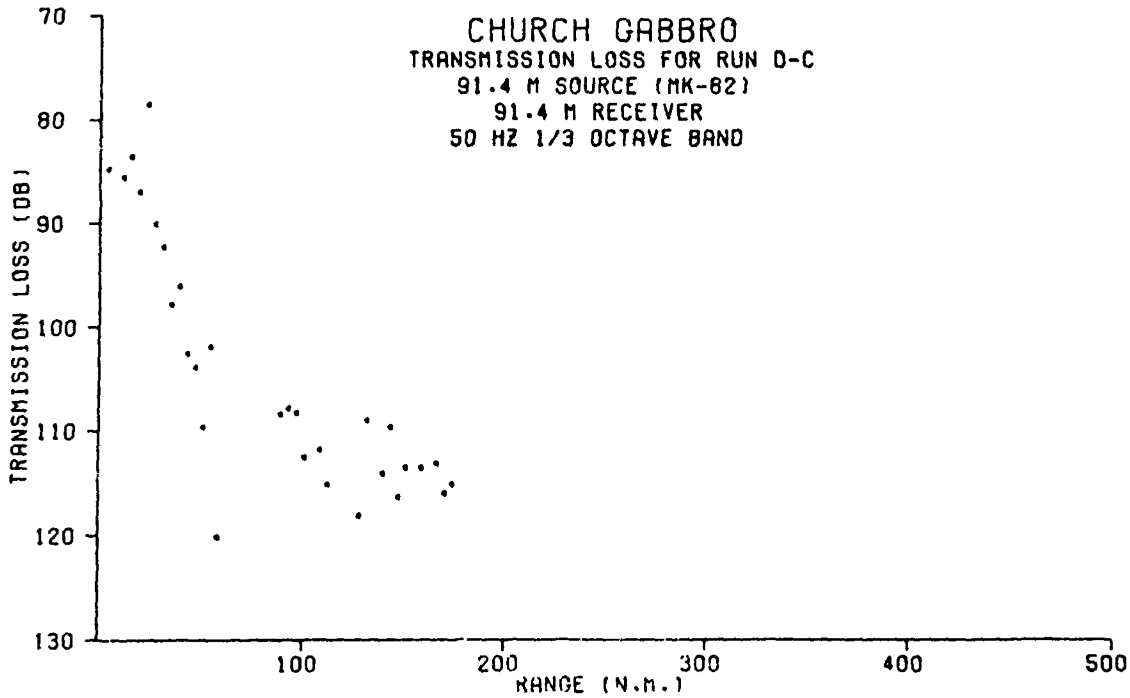
(Computations by Naval Underwater Systems Center, New London Laboratory)

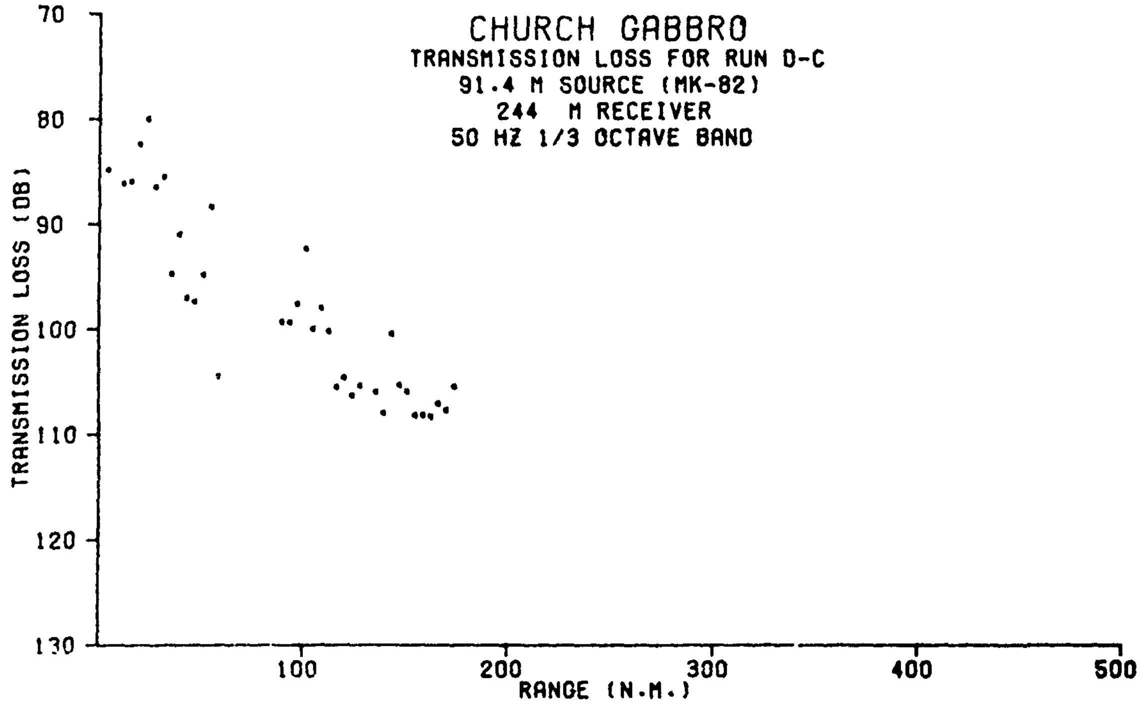

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
25 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

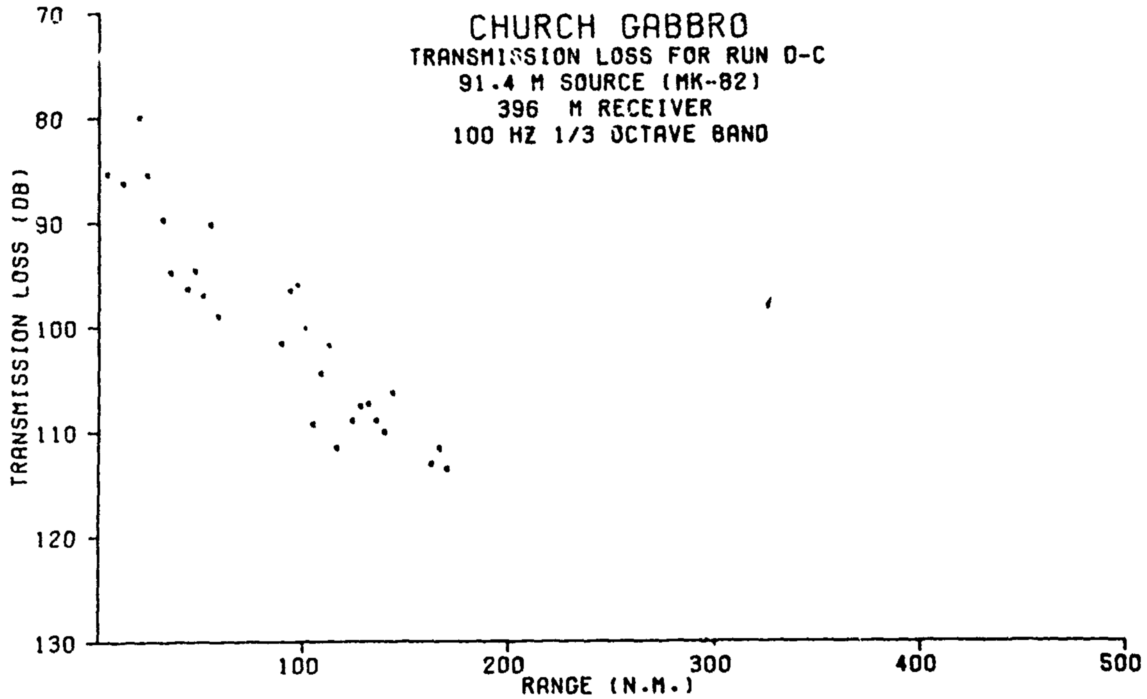

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

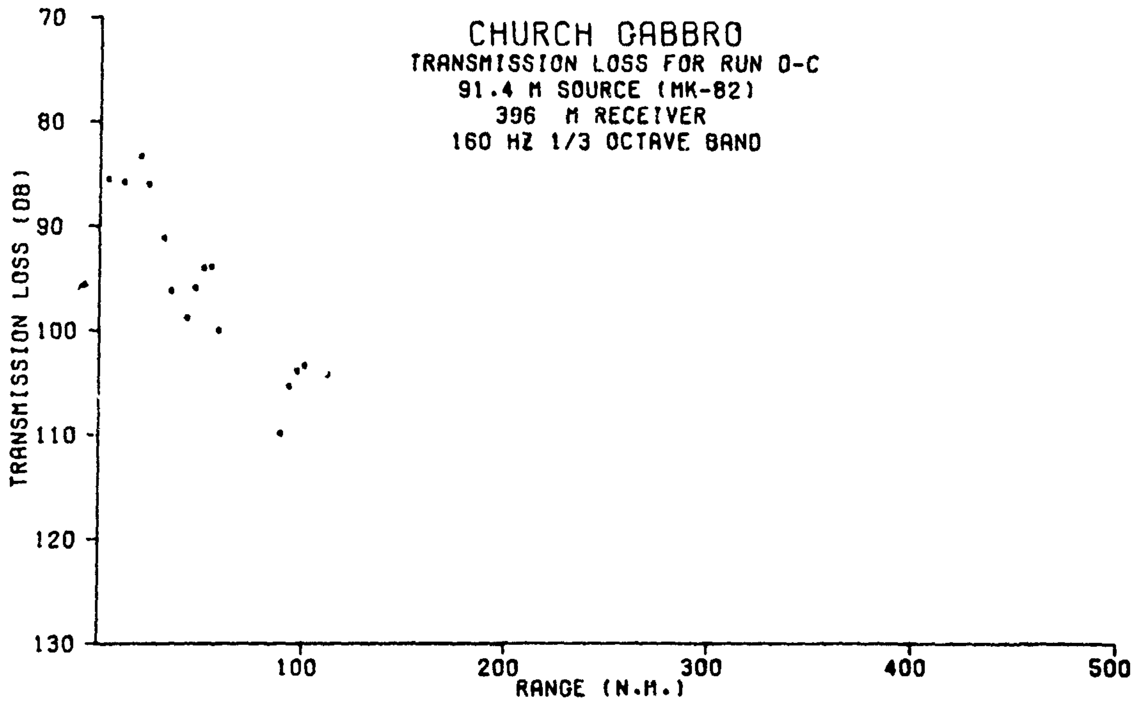

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
18.3 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

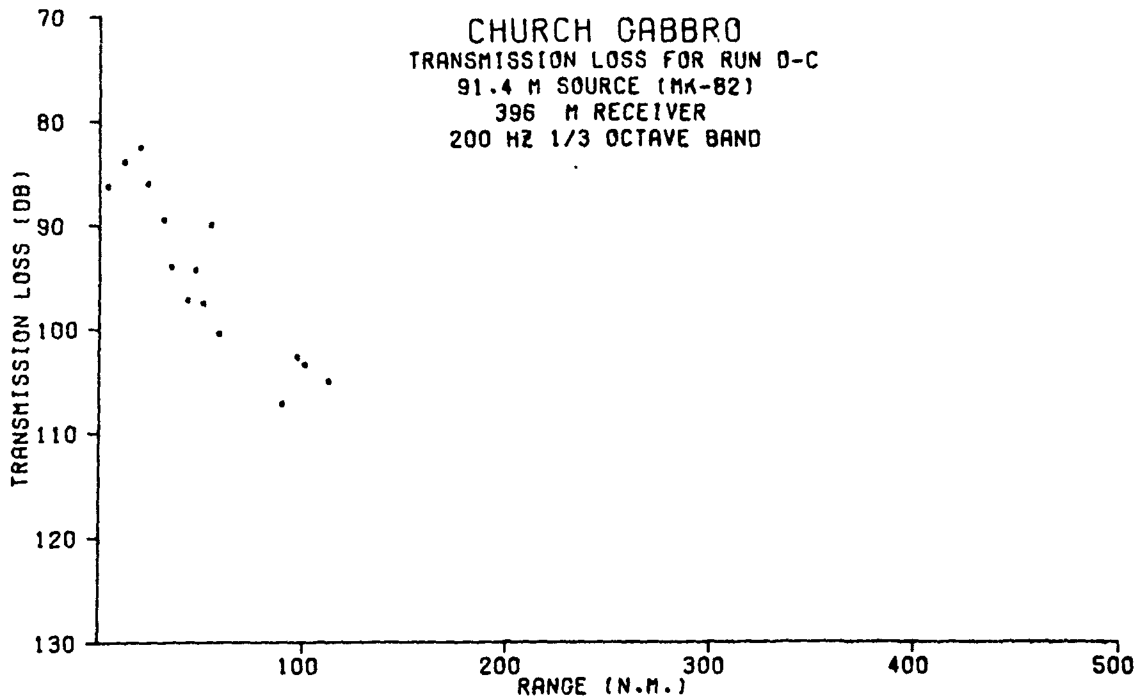
61

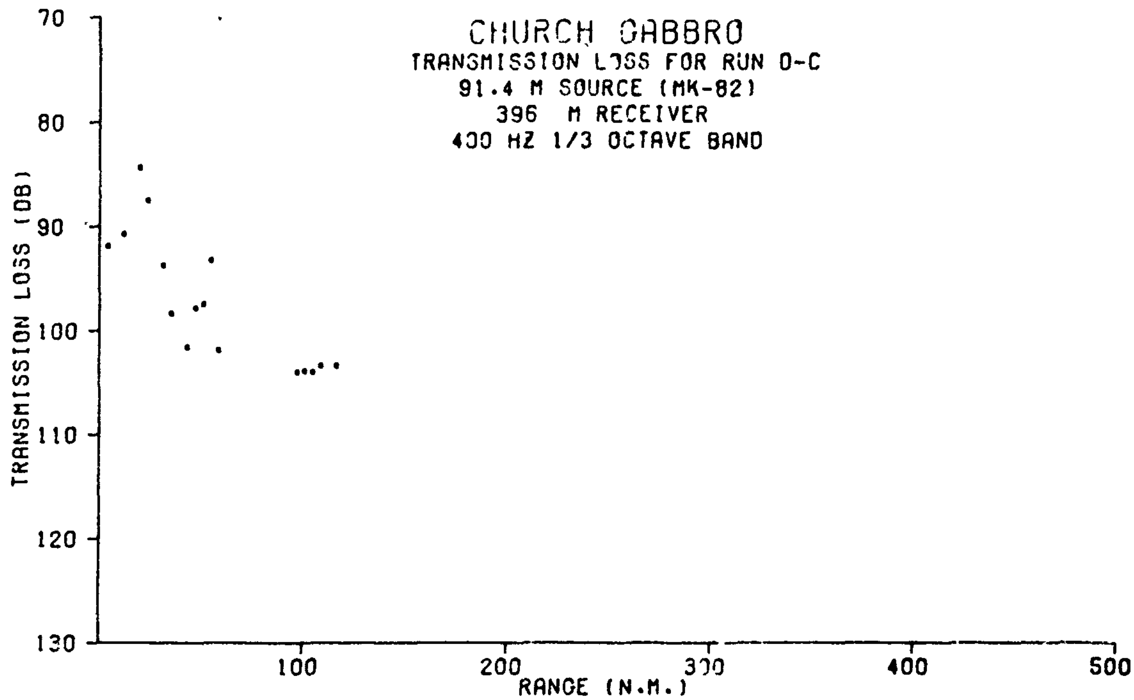

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
91.4 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

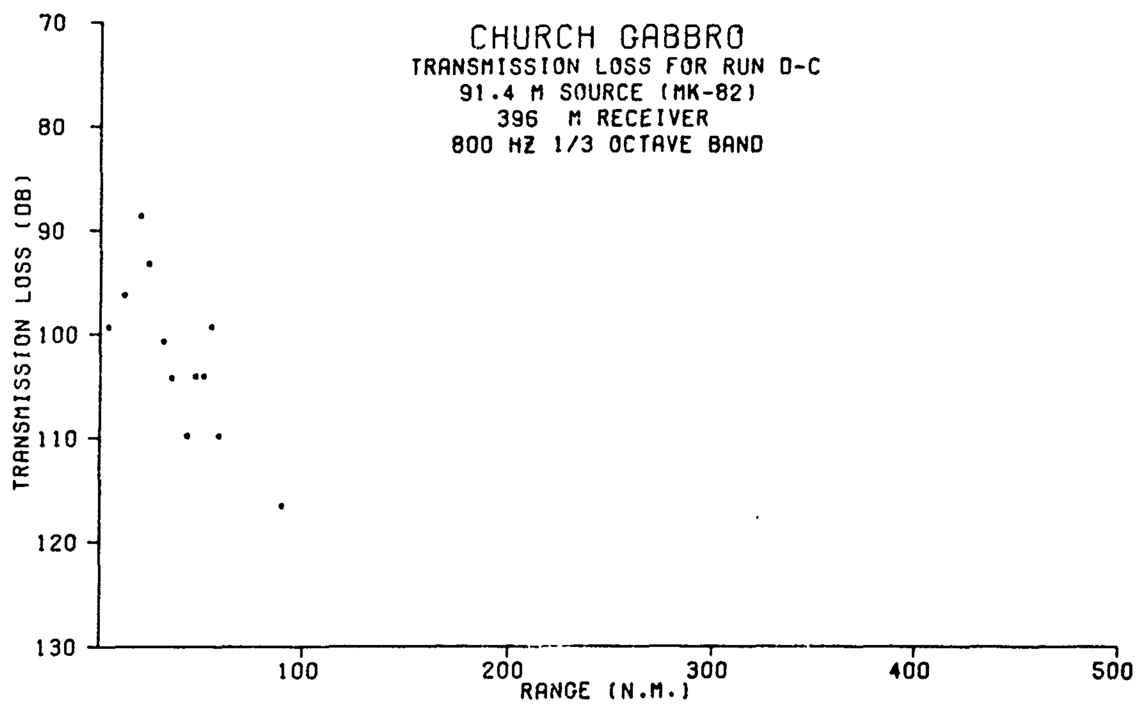

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
244 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
100 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN O-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
160 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN O-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
200 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
400 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN D-C
91.4 M SOURCE (MK-82)
396 M RECEIVER
800 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

APPENDIX H

-

TRANSMISSION LOSS COMPUTED FROM

AIRCRAFT SUS RUN DATA

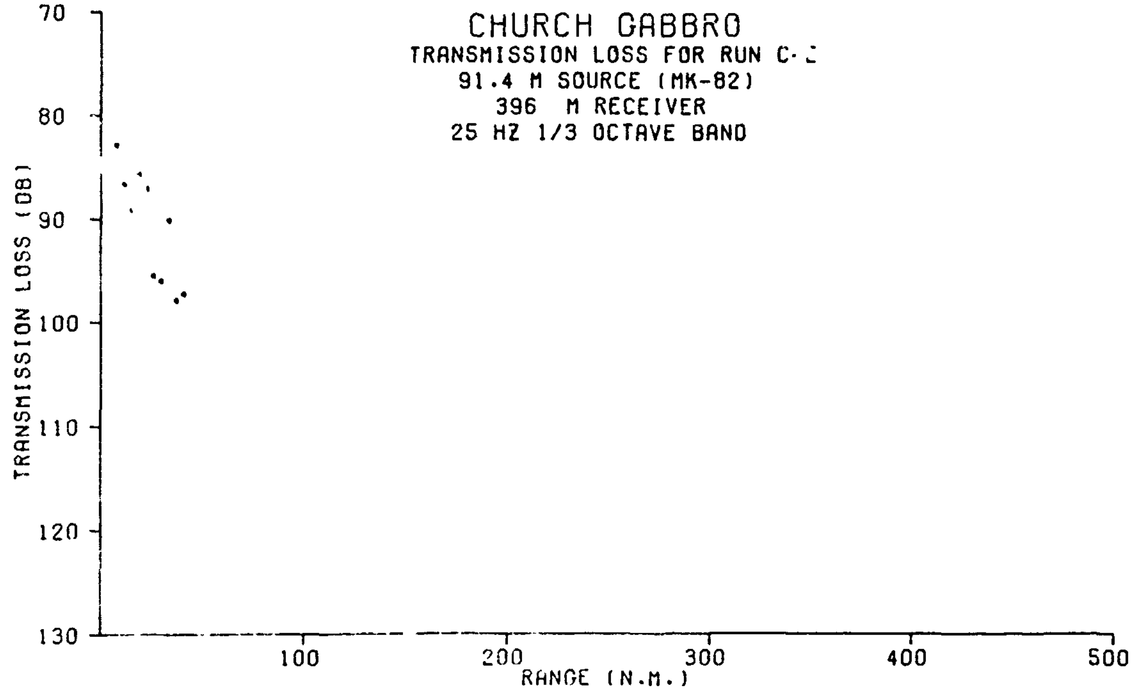
FROM POSIT C

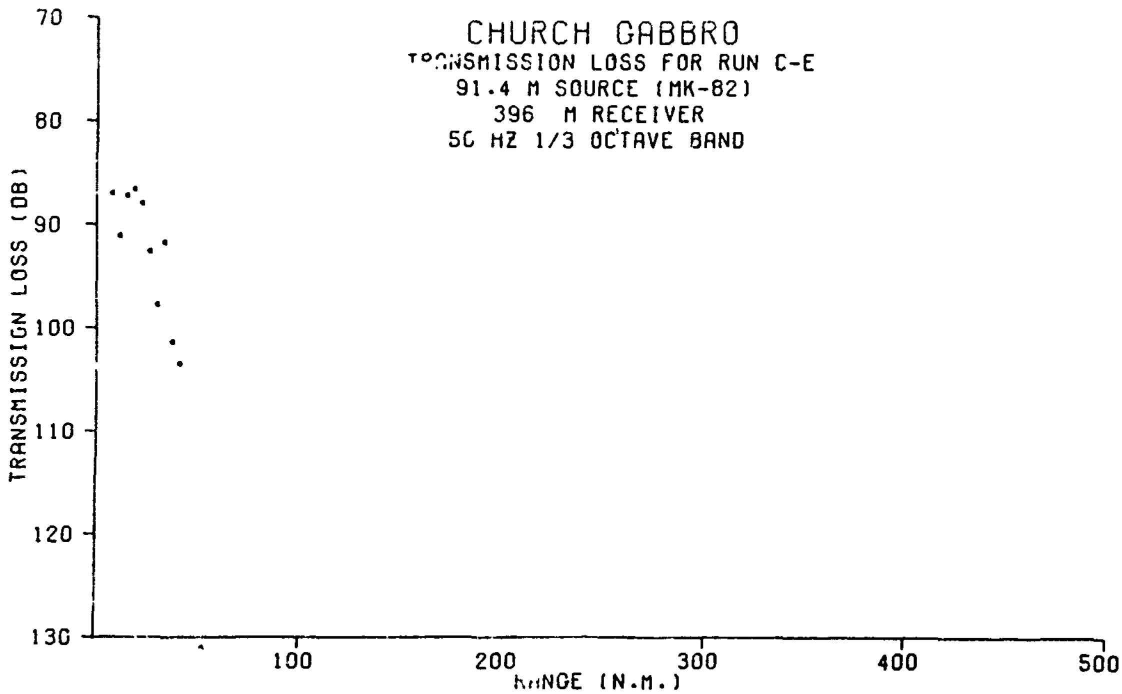
TO POSIT E

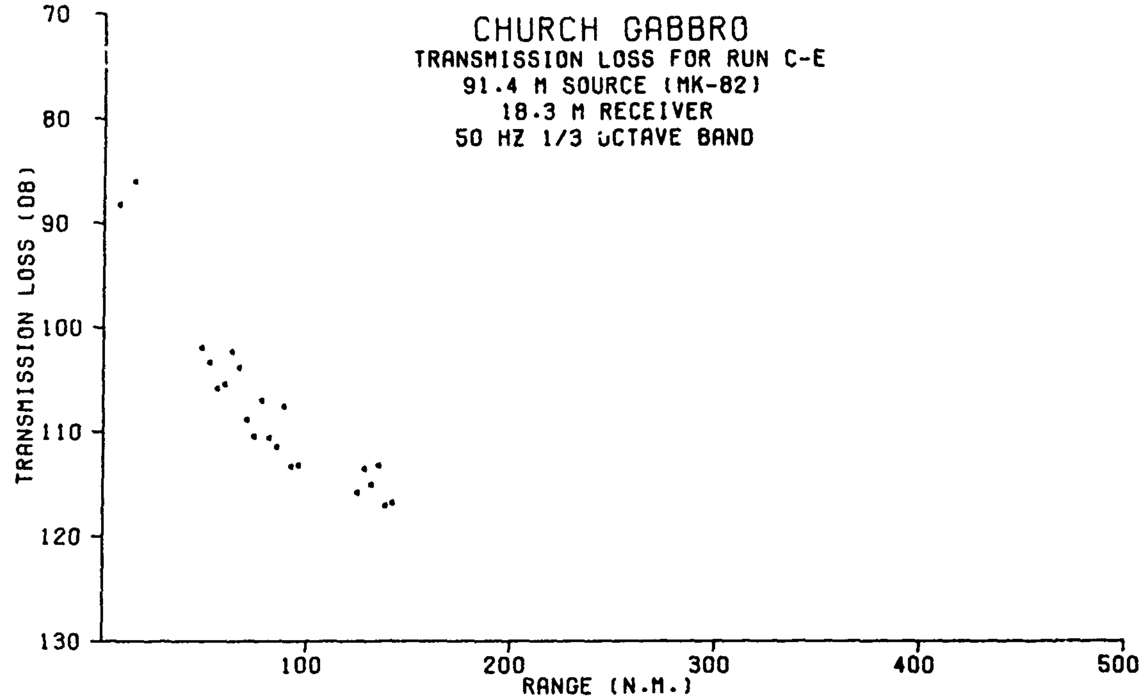
-

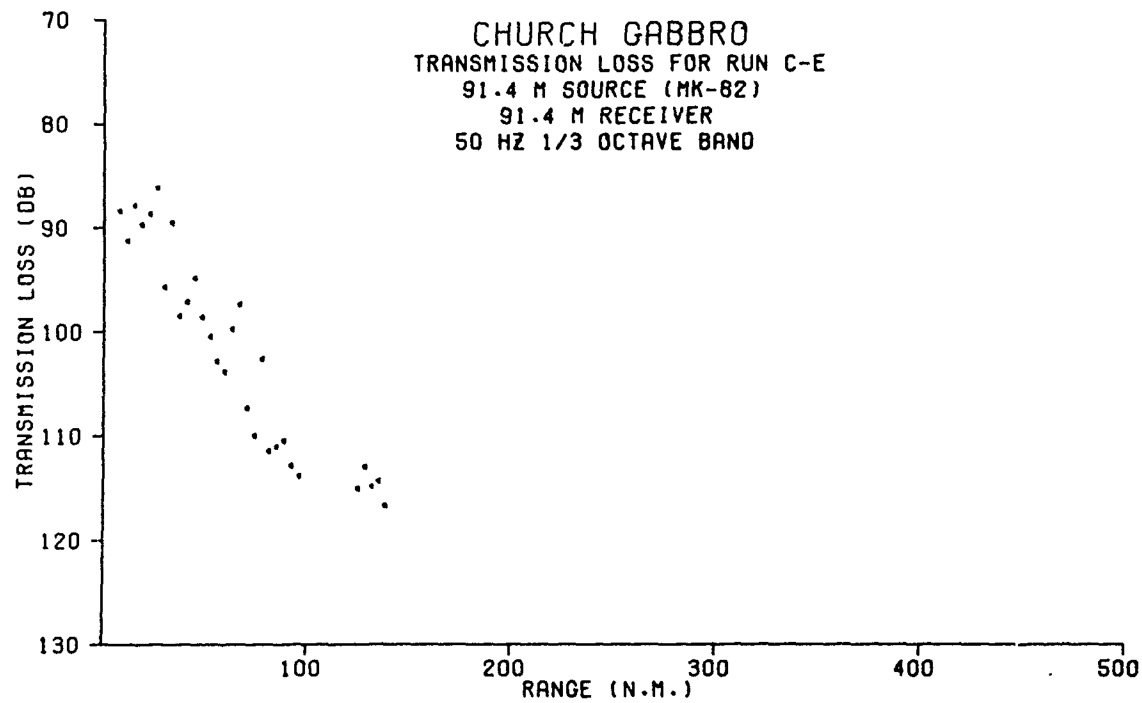
RECEIVING SYSTEMS TABS AND SONOBUOYS AT POSIT C

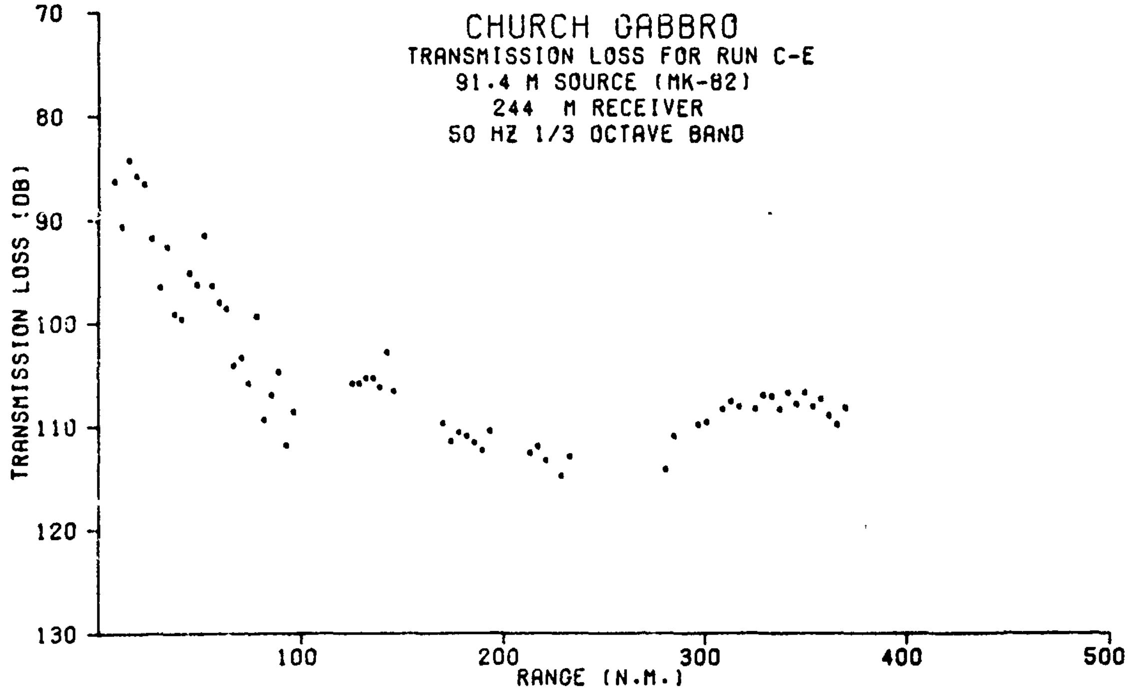
(Computations by Naval Underwater Systems Center. New London Laboratory)

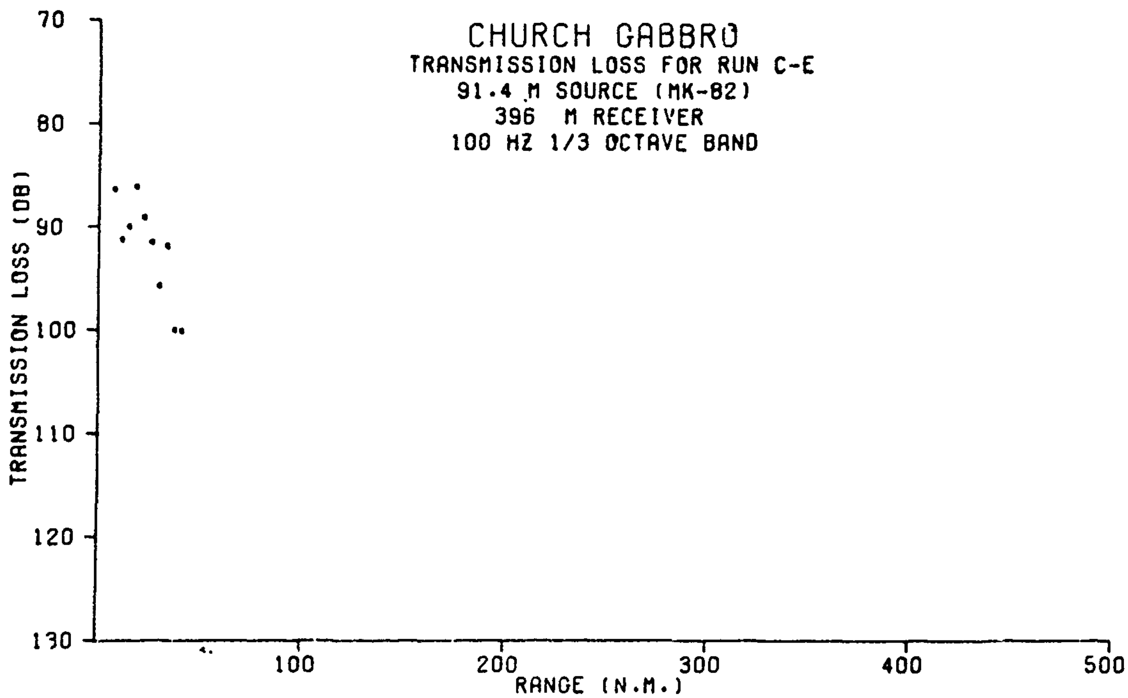

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-
91.4 M SOURCE (MK-82)
396 M RECEIVER
25 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

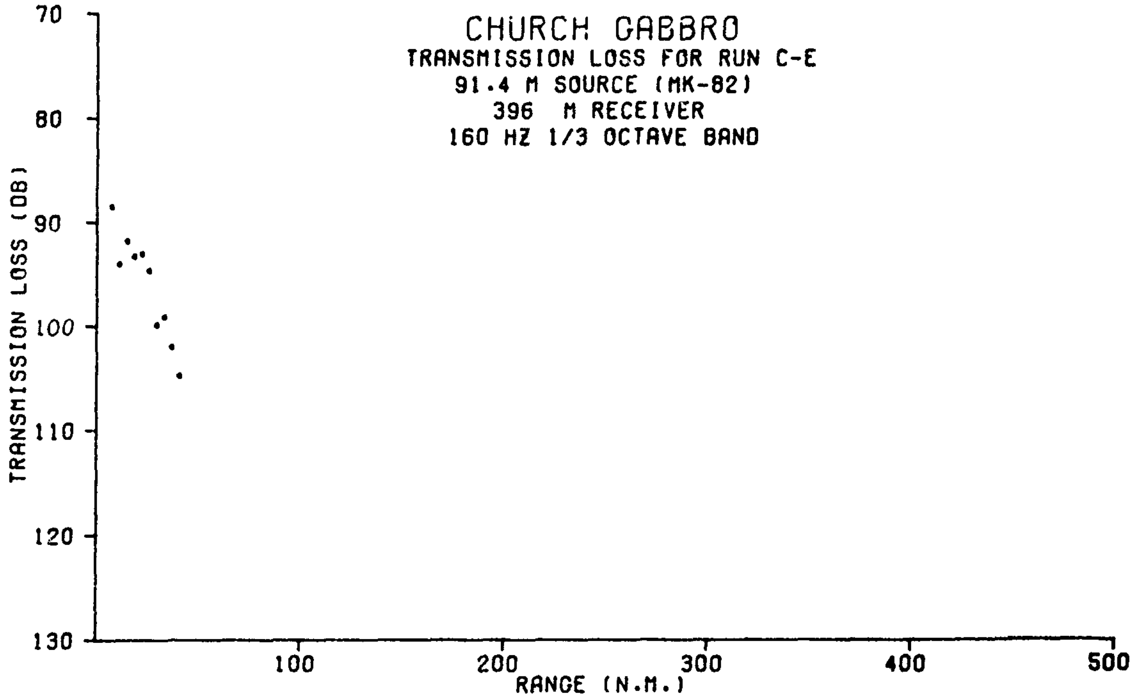

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
396 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

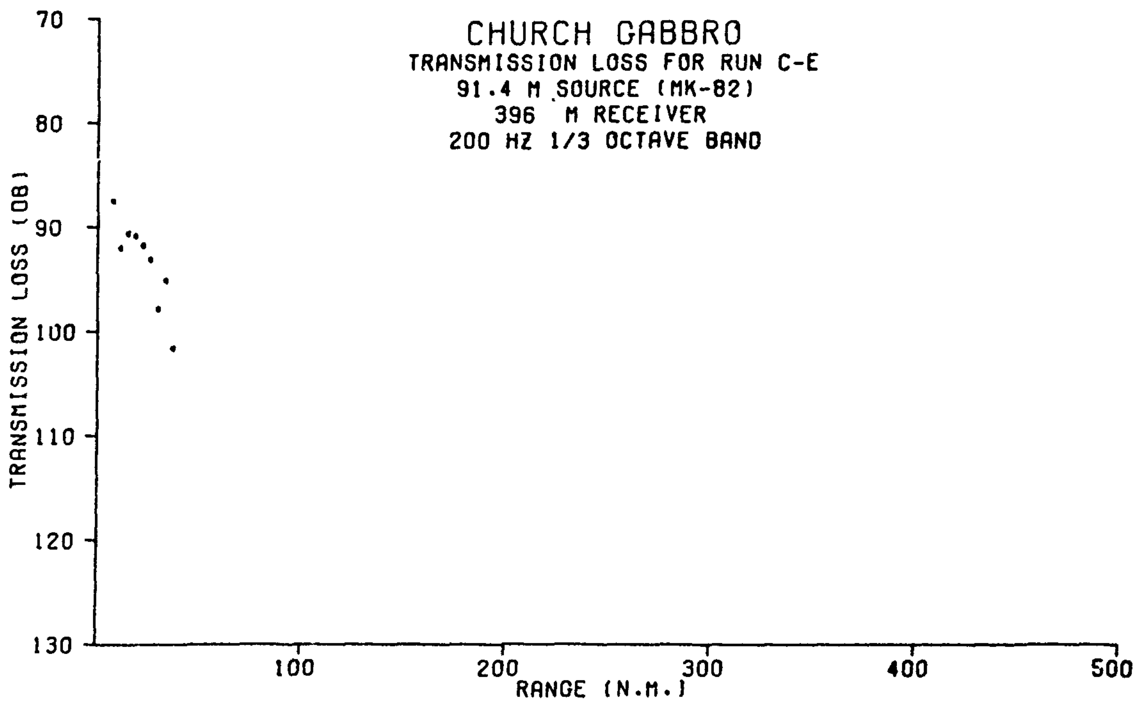

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
18.3 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

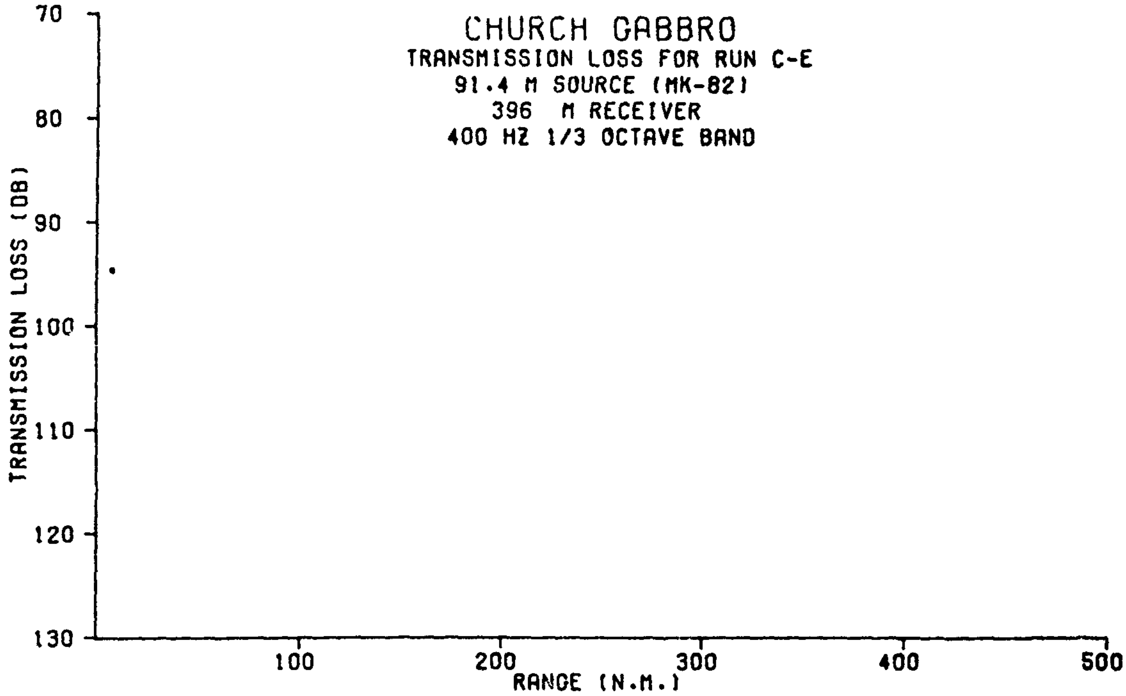

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
91.4 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

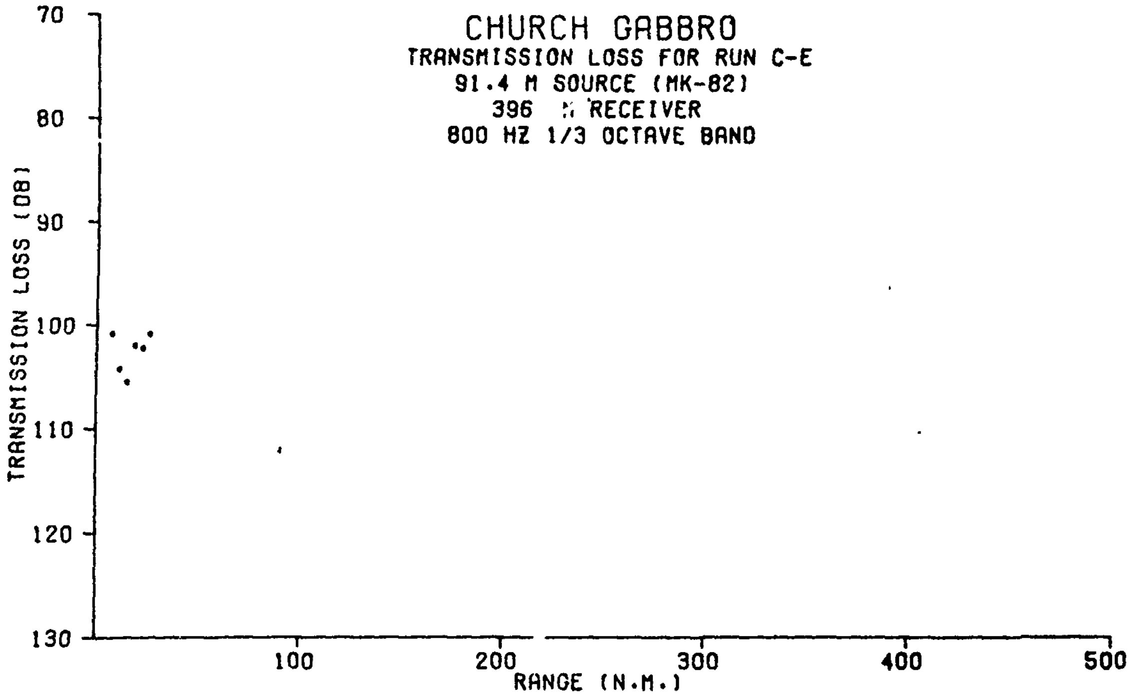

CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
244 M RECEIVER
50 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
396 M RECEIVER
100 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
396 M RECEIVER
160 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
396 M RECEIVER
200 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
396 M RECEIVER
400 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)


CHURCH GABBRO
TRANSMISSION LOSS FOR RUN C-E
91.4 M SOURCE (MK-82)
396 M RECEIVER
800 HZ 1/3 OCTAVE BAND
TRANSMISSION LOSS (DB)
70
80
90
100
110
120
130
100
200
300
400
500
RANGE (N.M.)

APPENDIX I

-

INTER-HYDROPHONE

TRANSMISSION LOSS DIFFERENCE

COMPUTED FROM

NORTH SEAL SUS RUN DATA

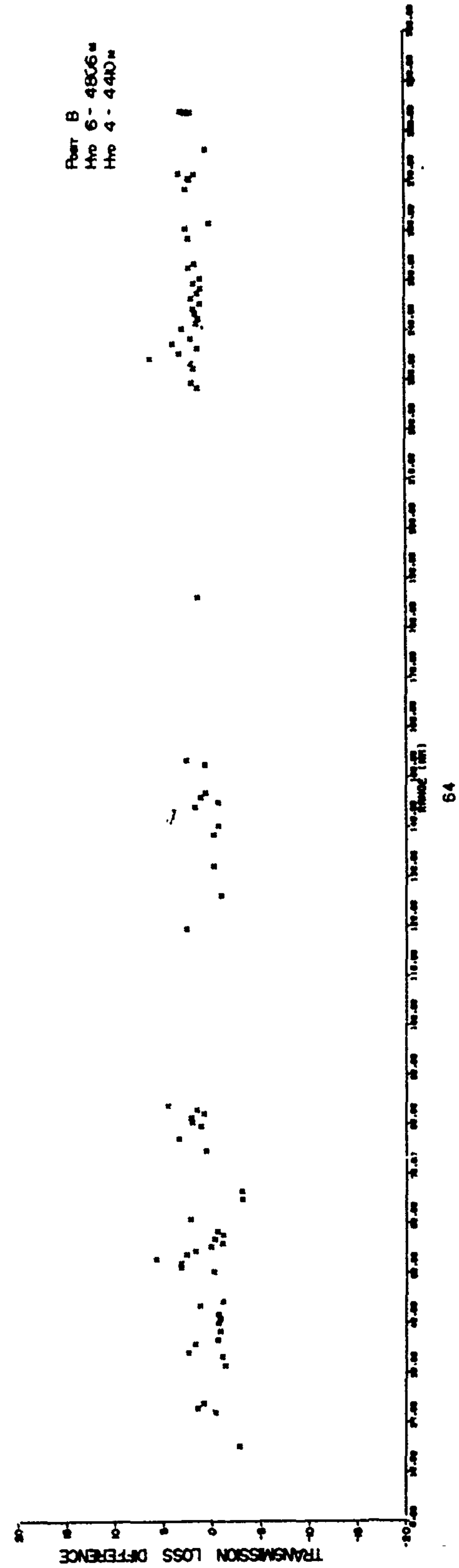
FROM POSIT E

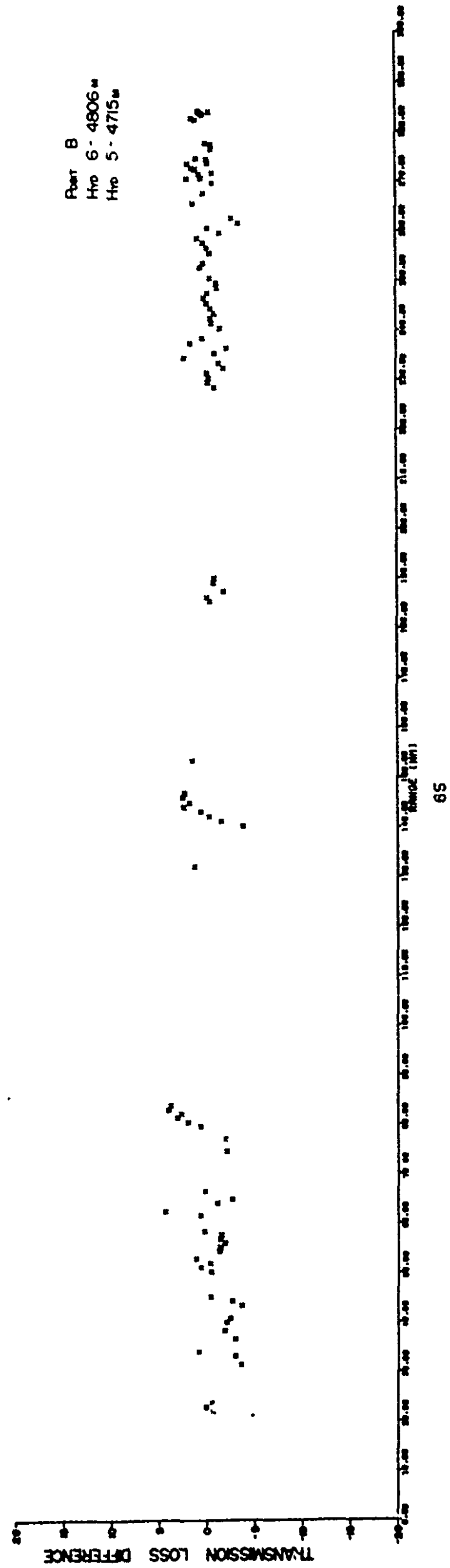
TO POSIT B

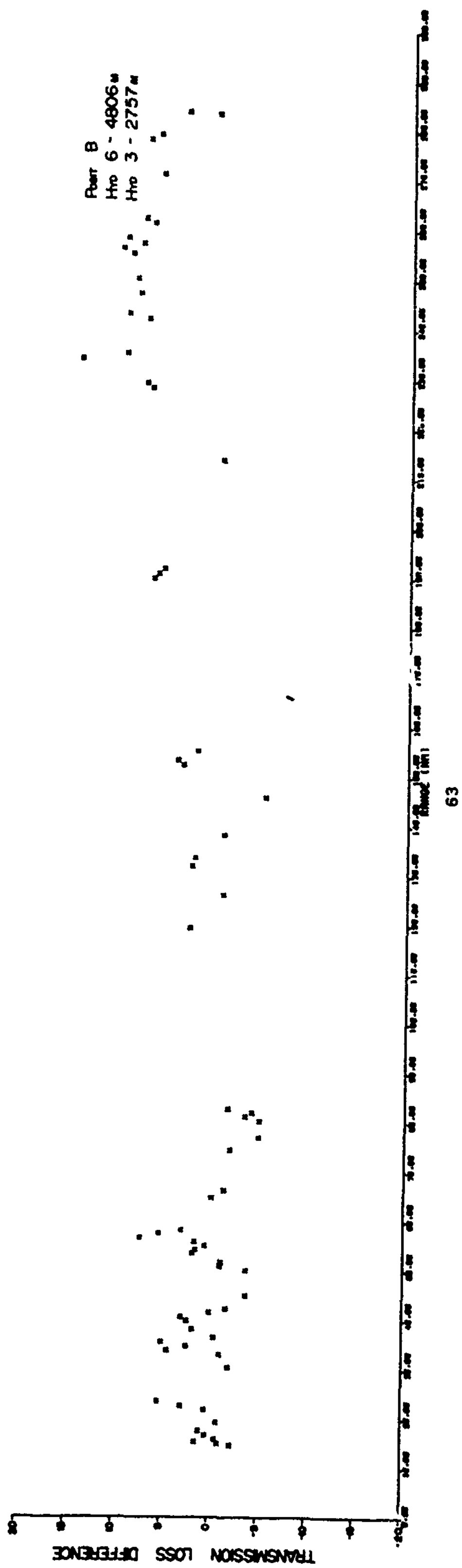
-

RECEIVING SYSTEM ACODAC AT POSIT B

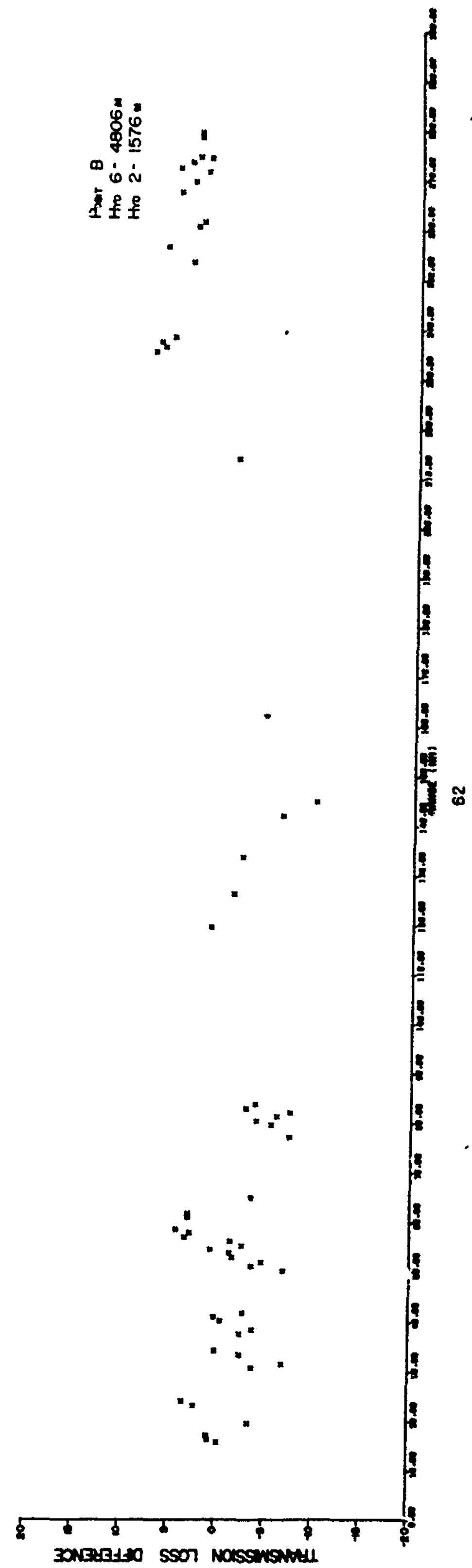
Contents: Pages:


Port B
Hyd 6 - 4806m
Hyd 4 - 4410m
TRANSMISSION LOSS DIFFERENCE
64

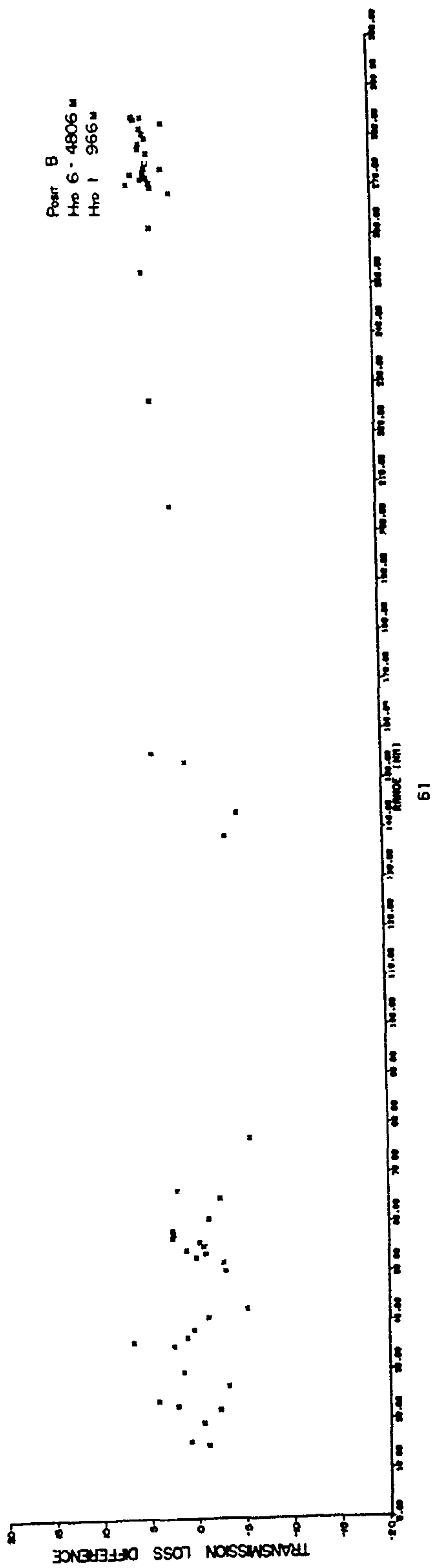

Port B
Hyd 6 - 4806m
Hyd 5 - 4715m
TRANSMISSION LOSS DIFFERENCE
65

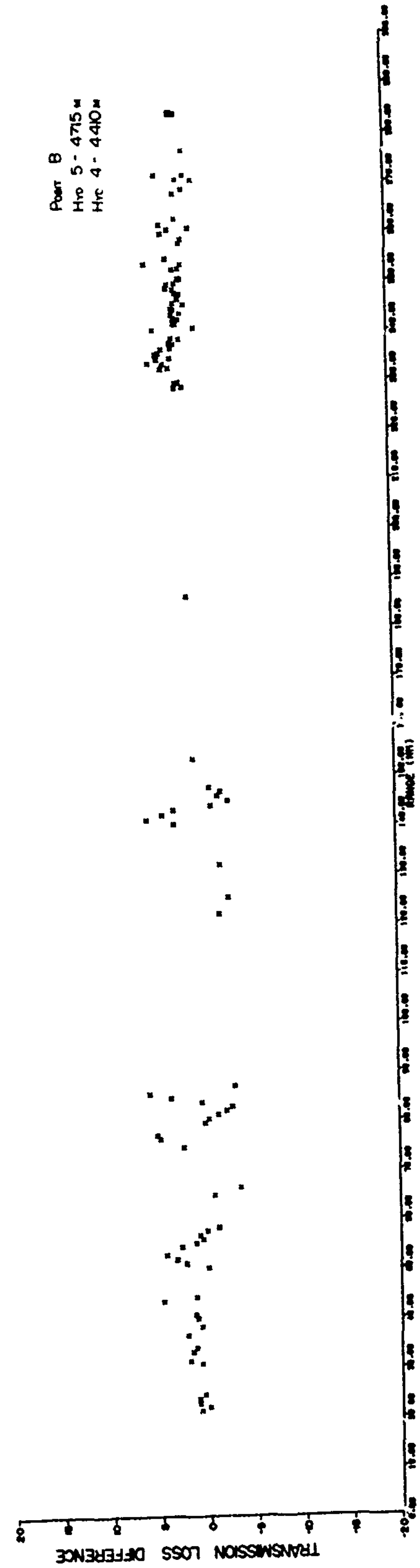


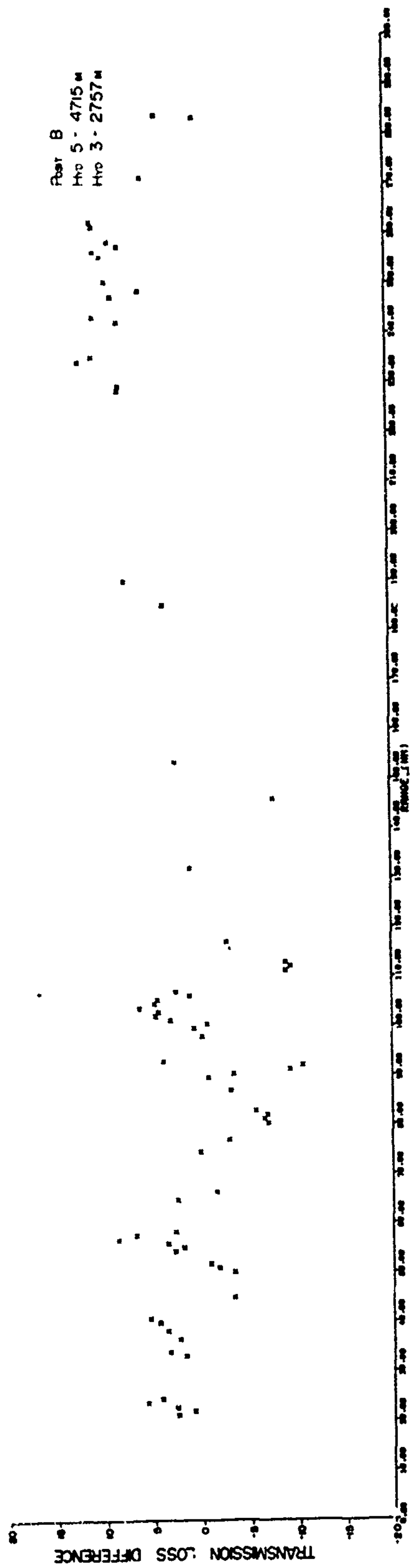
Pair B
Hro 6 - 4806 m
Hro 3 - 2757 m
TRANSMISSION LOSS DIFFERENCE
63



Pair B
Hro 6 - 4806 m
Hro 2 - 1576 m
TRANSMISSION LOSS DIFFERENCE
62


Port B
Hro 6 - 4806 m
Hro 1 966 m
TRANSMISSION LOSS DIFFERENCE

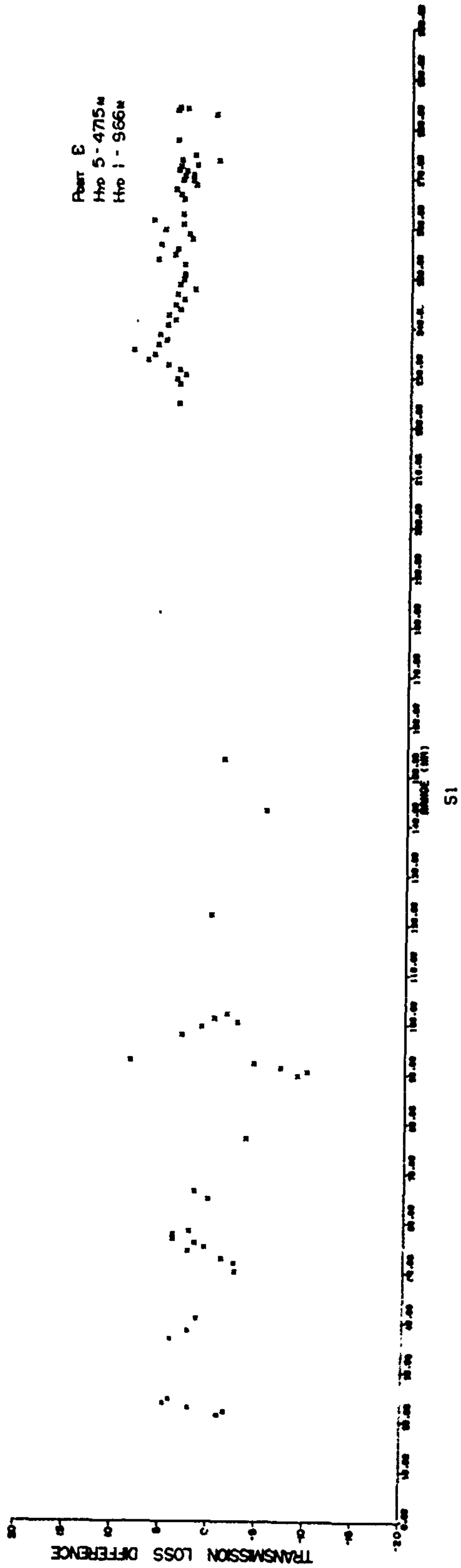

Port B
Hro 5 - 4715 m
Hrc 4 - 4410 m
TRANSMISSION LOSS DIFFERENCE

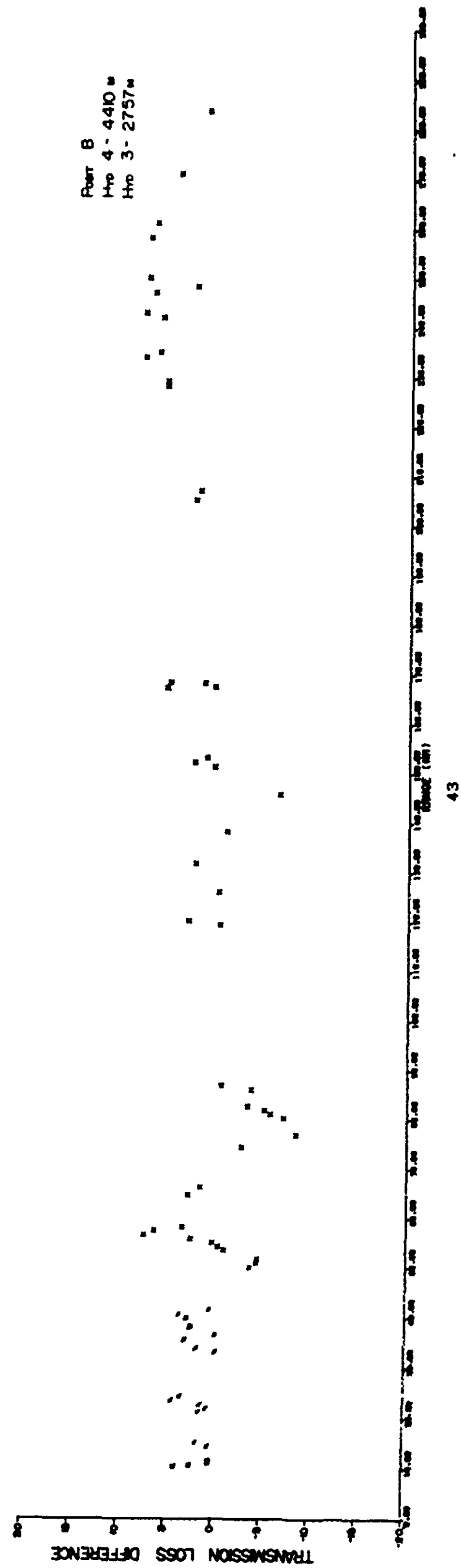

Port B
Hyd 5 - 4715 m
Hyd 3 - 2757 m
TRANSMISSION LOSS DIFFERENCE

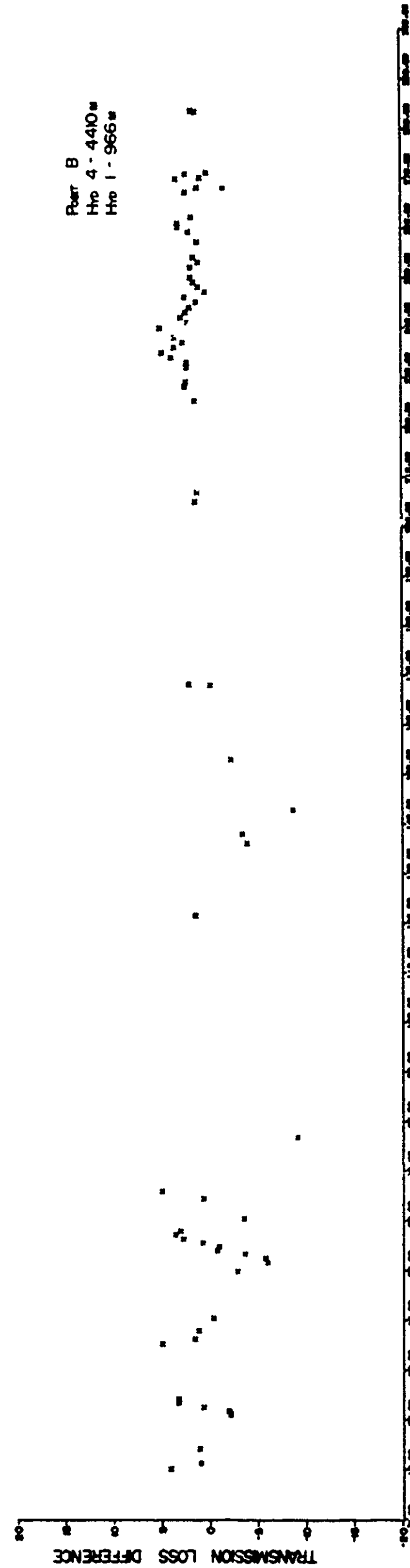
53


Port B
Hyd 5 - 4715 m
Hyd 2 - 1576 m
TRANSMISSION LOSS DIFFERENCE

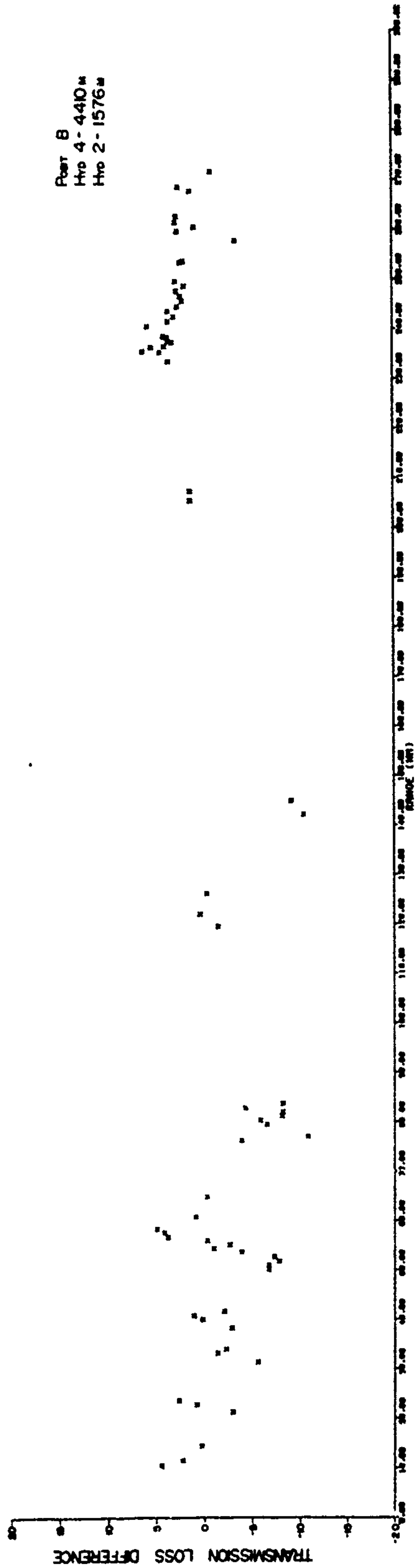
52


TRANSMISSION LOSS DIFFERENCE
51

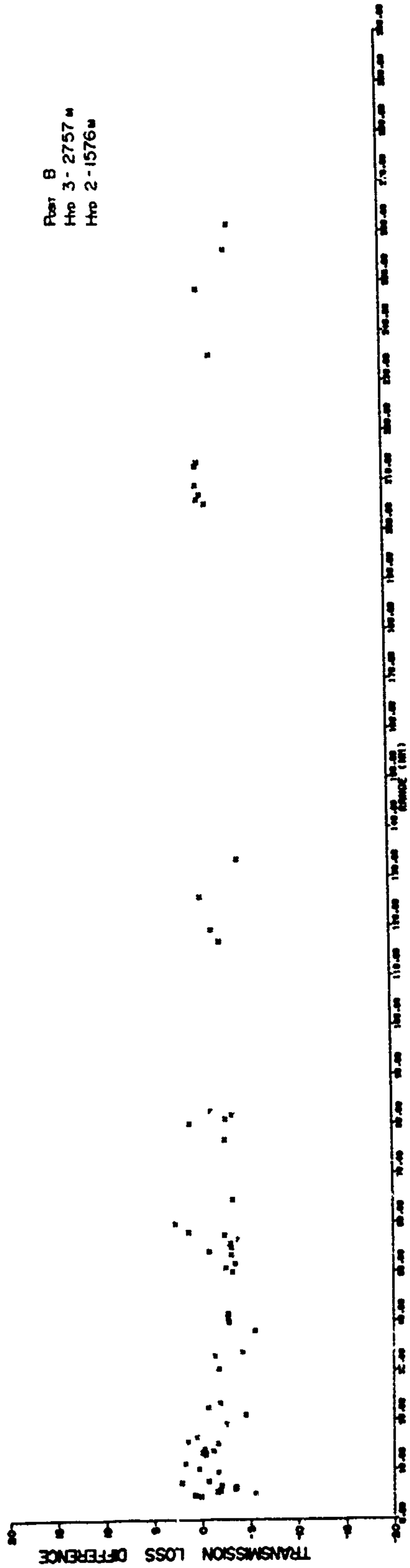

TRANSMISSION LOSS DIFFERENCE
43


Pair B
Hyd 4 - 4410m
Hyd 1 - 966m
TRANSMISSION LOSS DIFFERENCE
RANGE (KM)

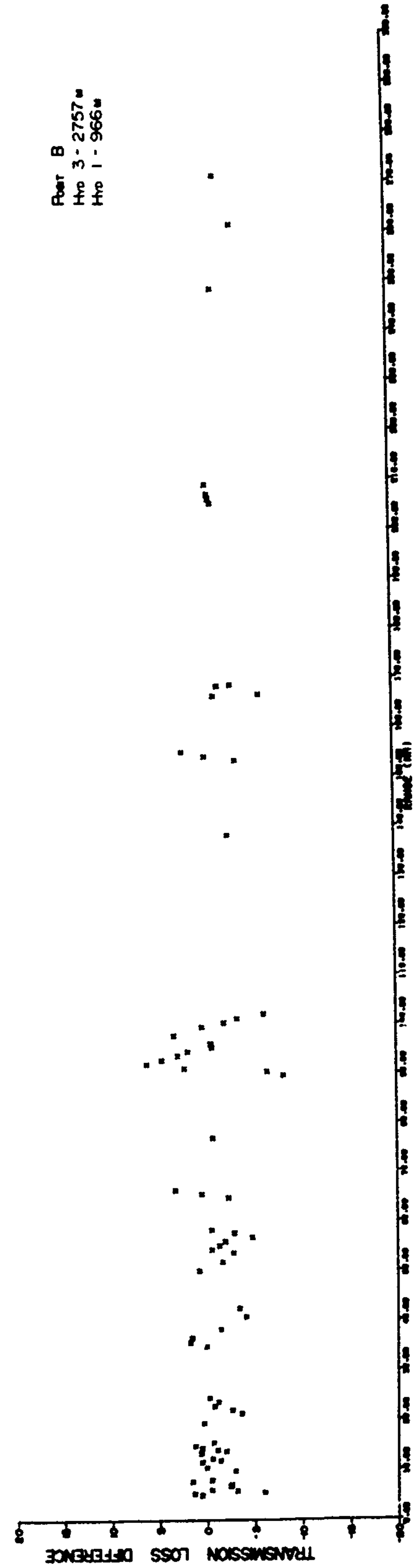
41


Pair B
Hyd 4 - 4410m
Hyd 2 - 1576m
TRANSMISSION LOSS DIFFERENCE
RANGE (KM)

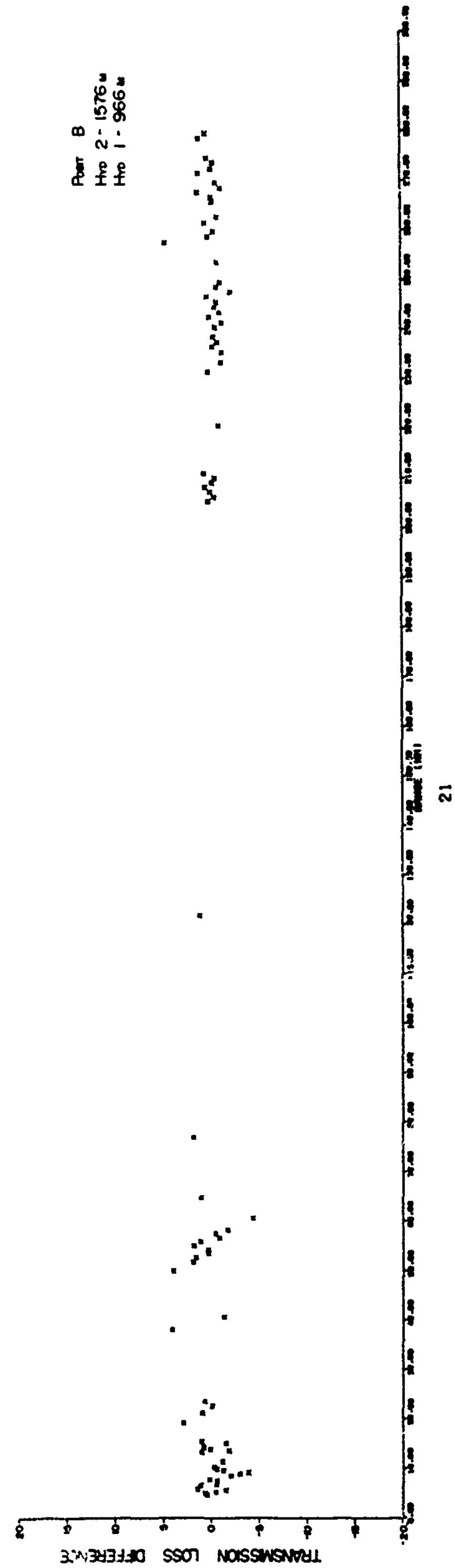
42

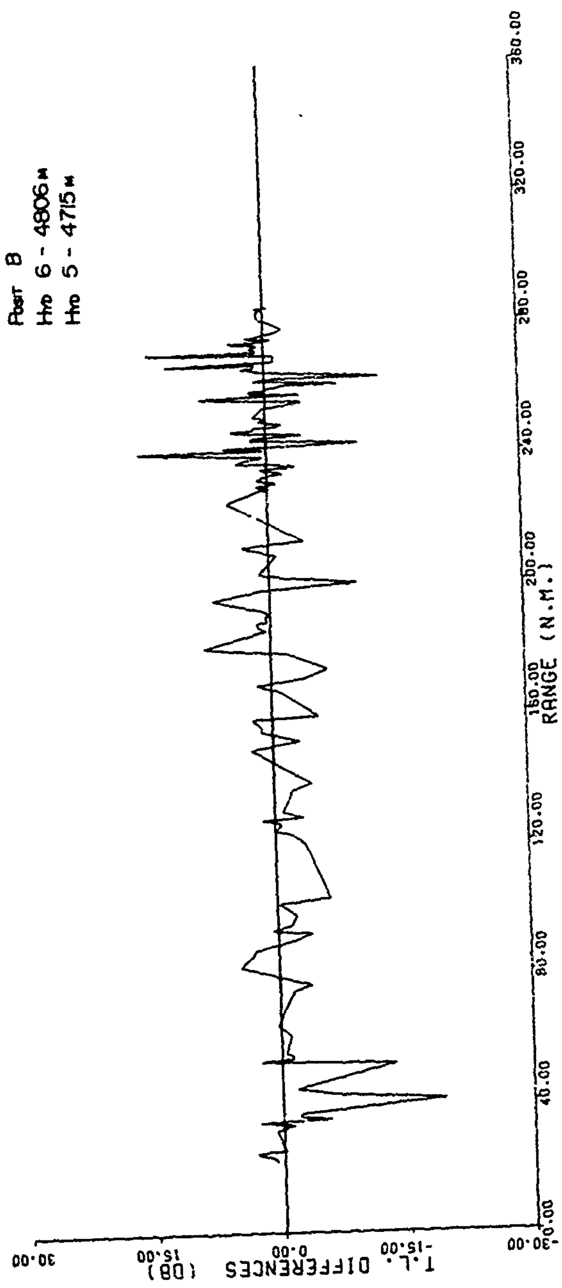

TRANSMISSION LOSS DIFFERENCE

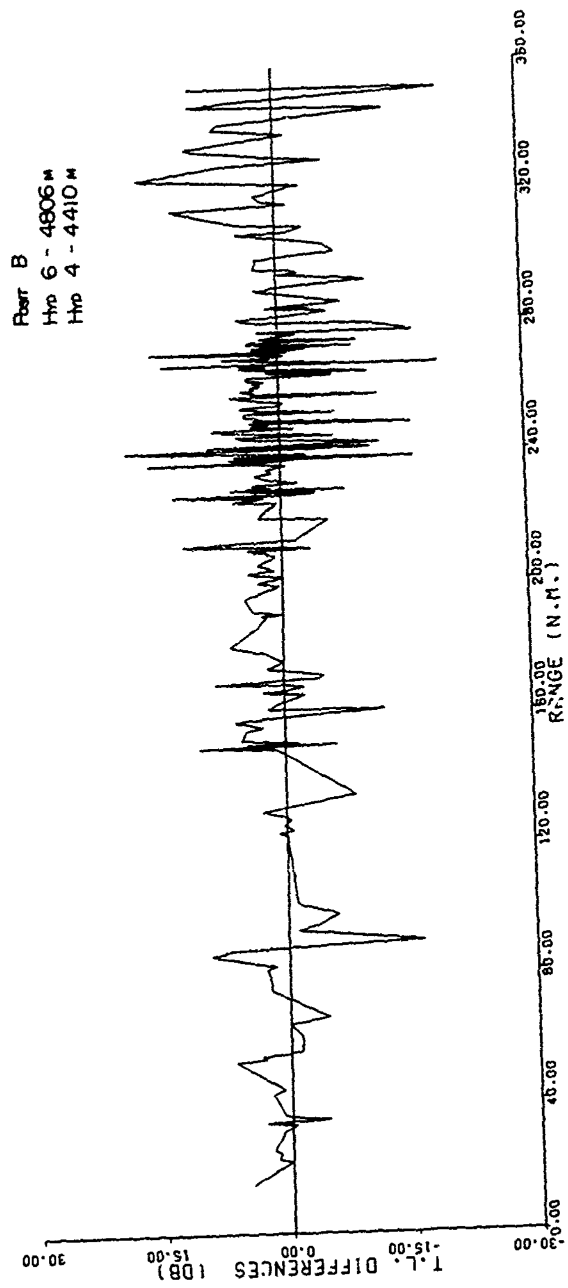
32

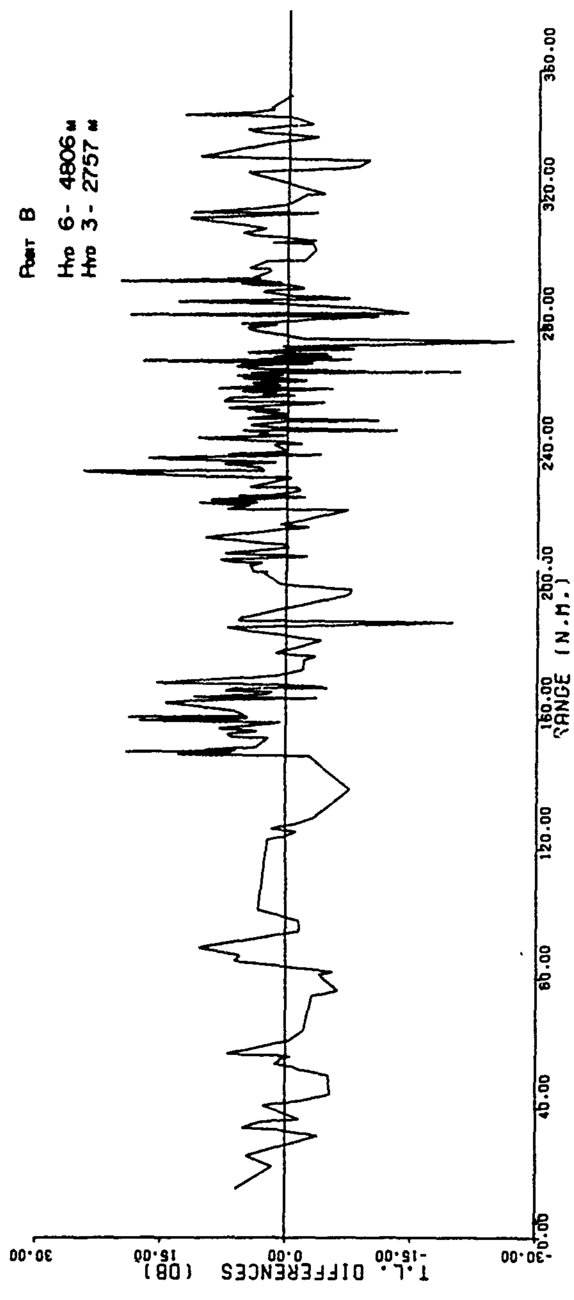

TRANSMISSION LOSS DIFFERENCE

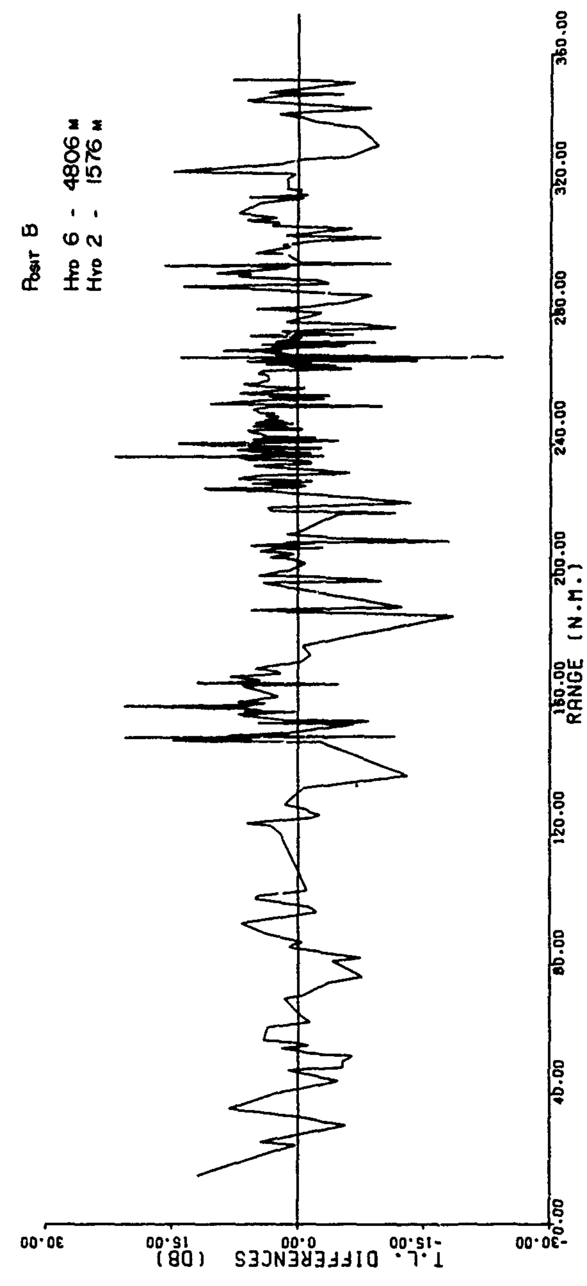
31


Pair B
TRANSMISSION LOSS DIFFERENCE
21

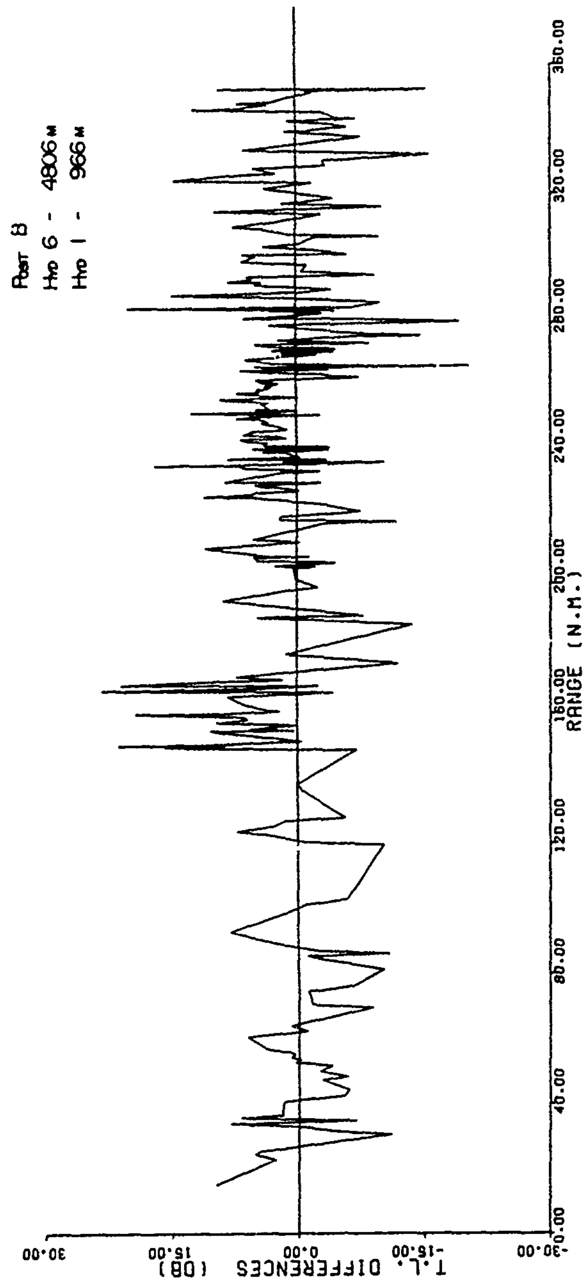

Part B
Hyd 6 - 4806M
Hyd 5 - 4715M
RANGE (N.M.)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
T.L. DIFFERENCES (DB)
-30.00
-15.00
0.00
15.00
30.00

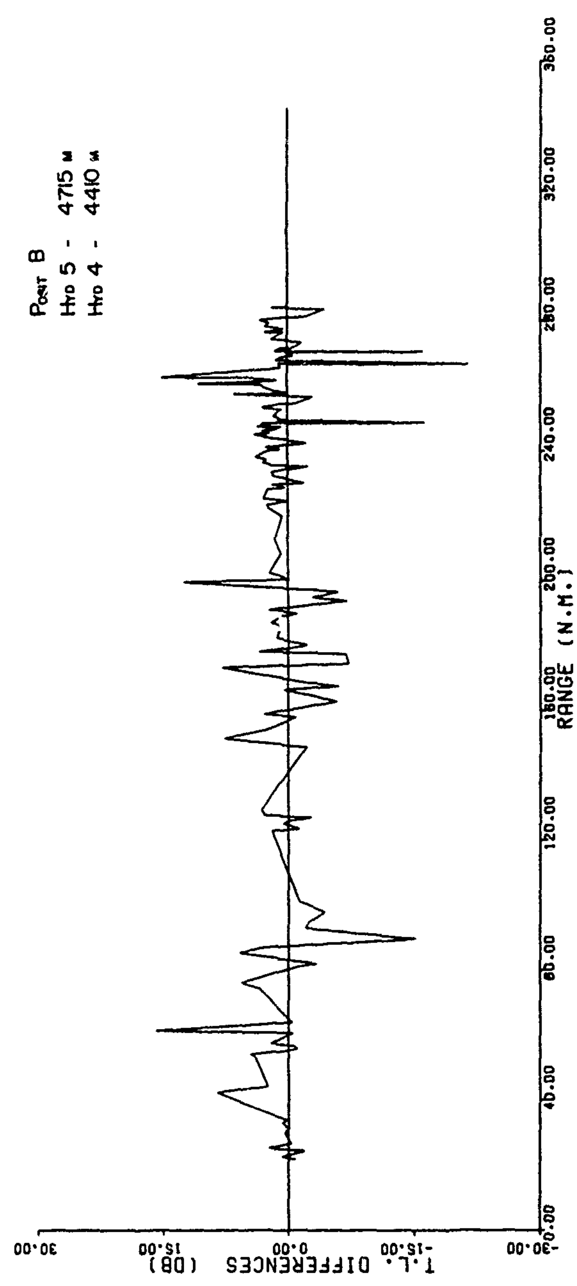

Part B
Hyd 6 - 4806M
Hyd 4 - 4410M
RANGE (N.M.)
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
320.00
360.00
T.L. DIFFERENCES (DB)
-30.00
-15.00
0.00
15.00
30.00


POSIT B
HYD 6 - 4806 M
HYD 3 - 2757 M
RANGE (N.M.)
T.L. DIFFERENCES (DB)


POSIT B
HYD 6 - 4806 M
HYD 2 - 1576 M
RANGE (N.M.)
T.L. DIFFERENCES (DB)

CONFIDENTIAL





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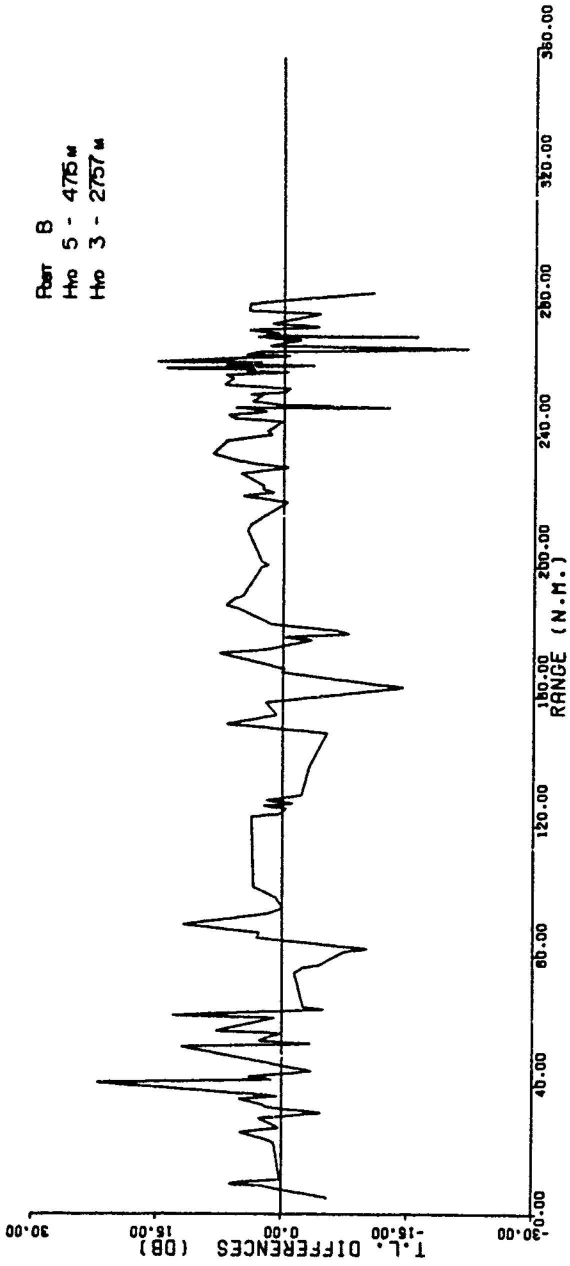
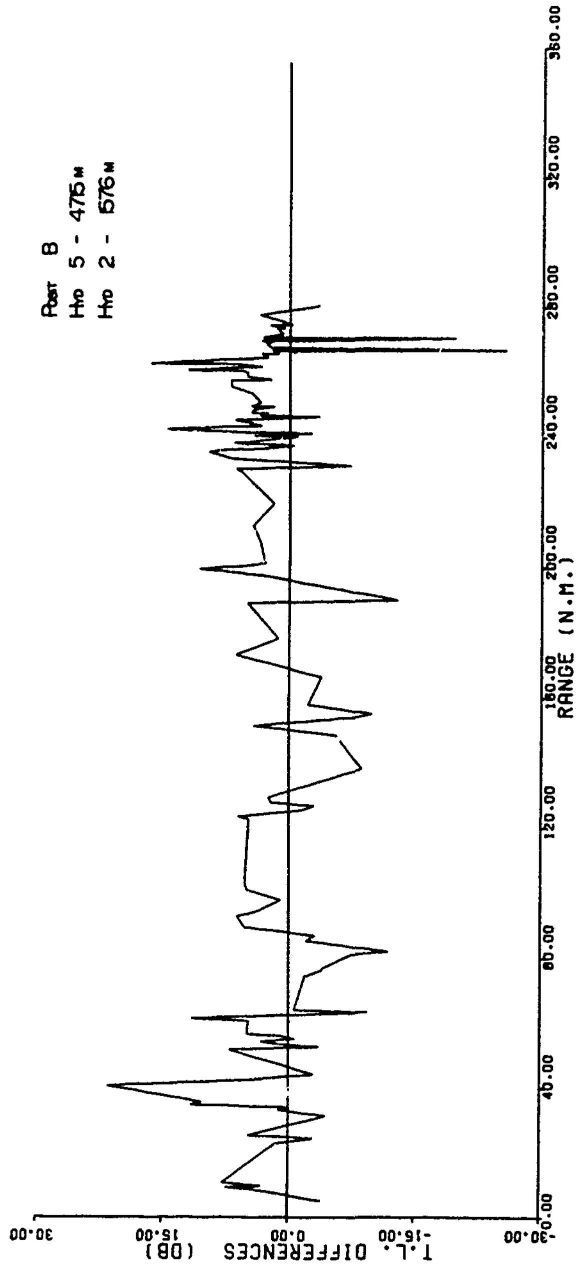

T.L. DIFFERENCES (DB)
RANGE (N.M.)


T.L. DIFFERENCES (DB)
RANGE (N.M.)

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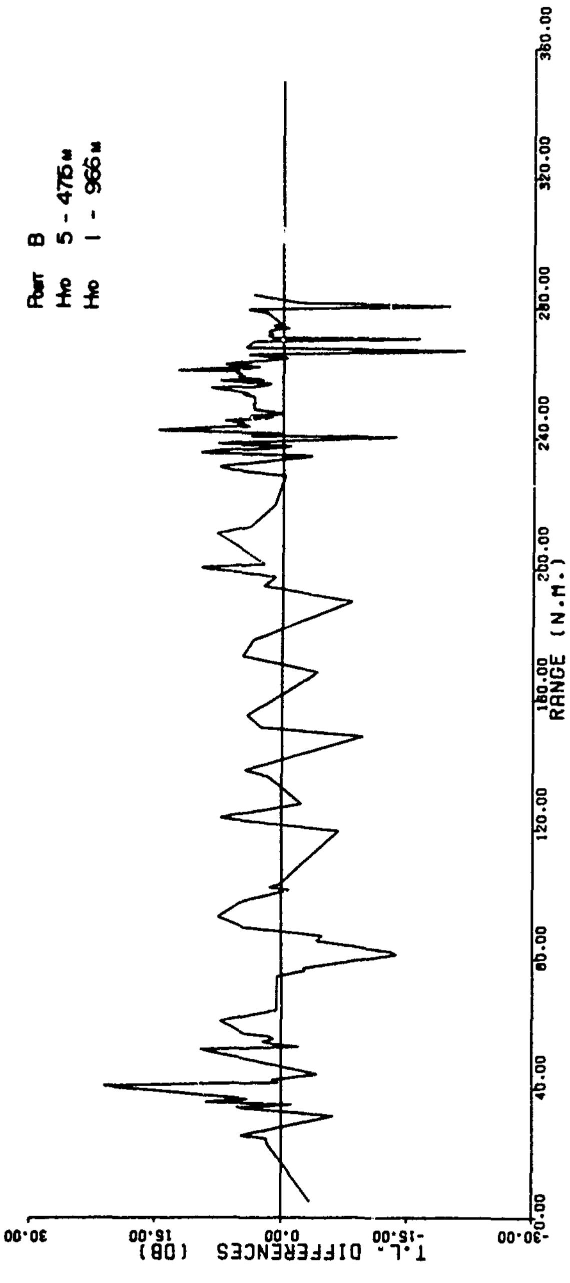

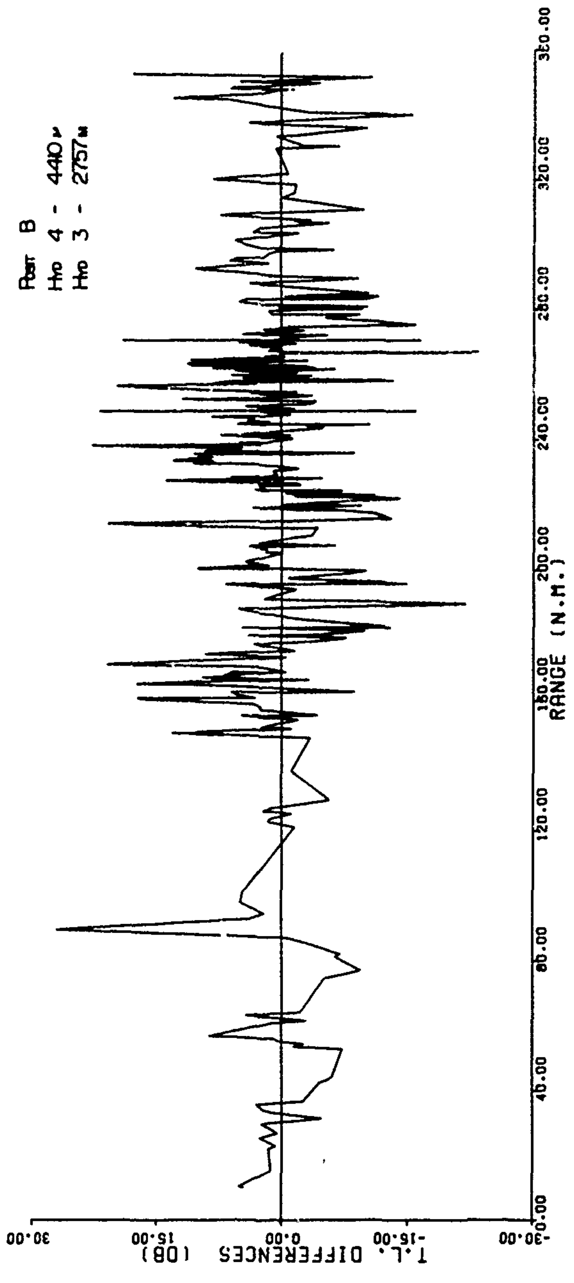

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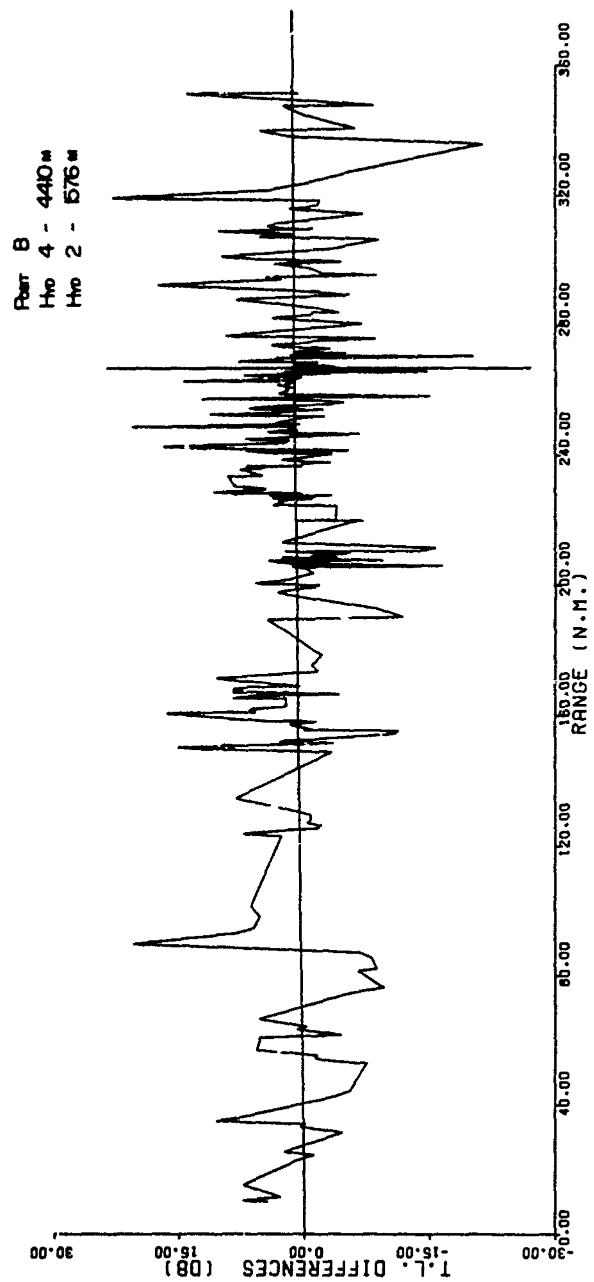
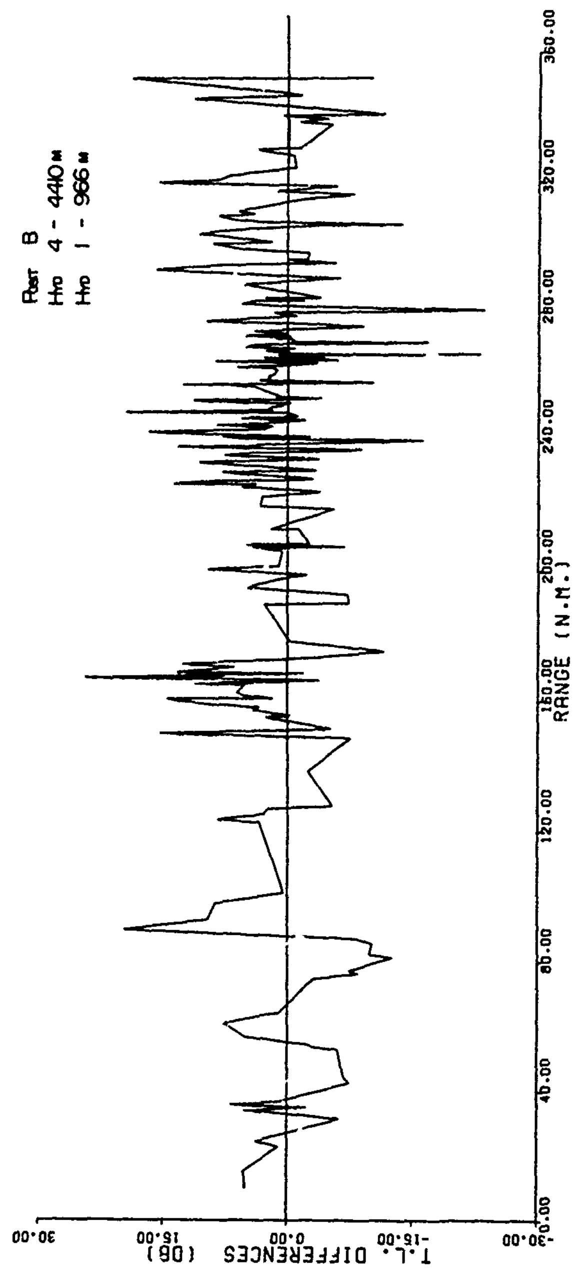
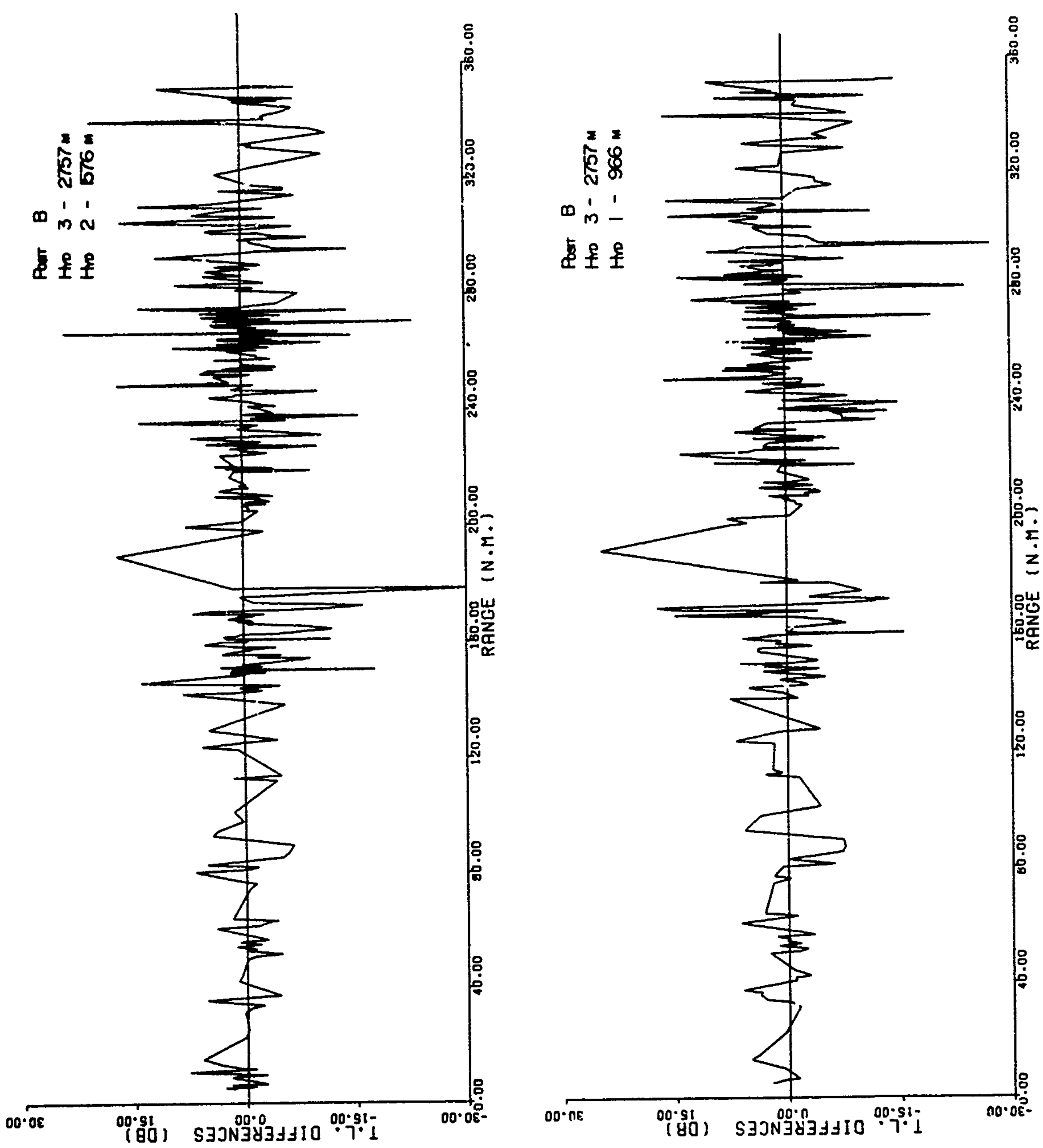
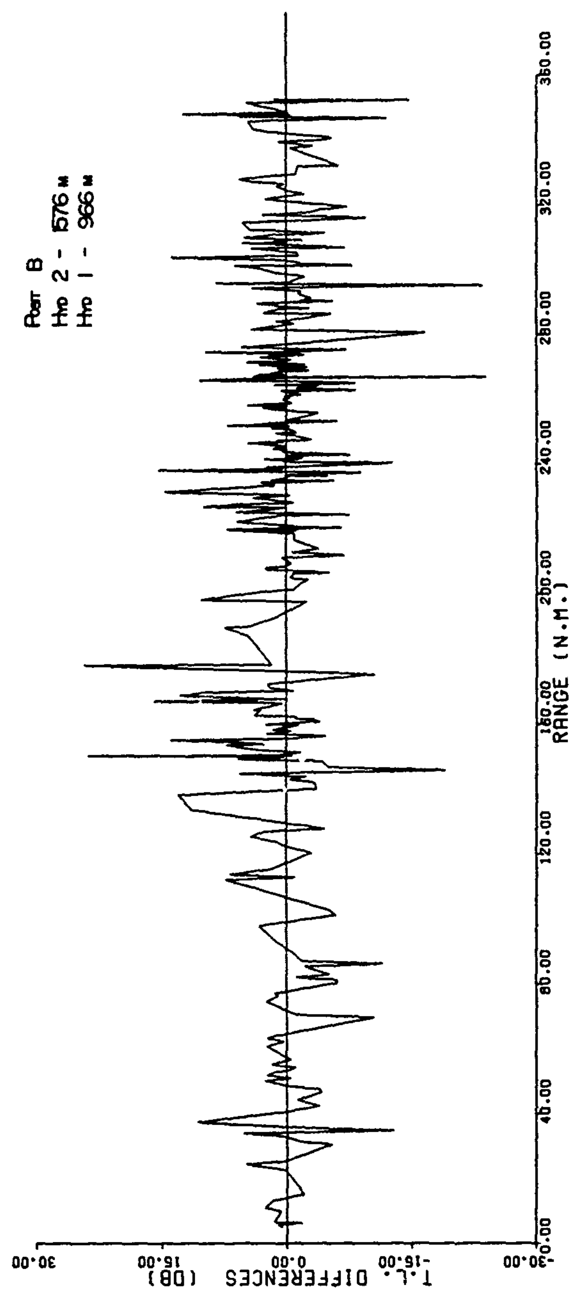

Part B
Hyd 4 - 4410 m
Hyd 2 - 1576 m
RANGE (N.M.)
T.L. DIFFERENCES (DB)


Part B
Hyd 4 - 4410 m
Hyd 1 - 966 m
RANGE (N.M.)
T.L. DIFFERENCES (DB)


Port B
Hyd 3 - 2757 m
Hyd 2 - 1576 m
Port B
Hyd 3 - 2757 m
Hyd 1 - 966 m
T.L. DIFFERENCES (DB)
RANGE (N.M.)
T.L. DIFFERENCES (DB)
RANGE (N.M.)

CONFIDENTIAL



CONFIDENTIAL

APPENDIX J

-

INTER-HYDROPHONE

TRANSMISSION LOSS DIFFERENCE

COMPUTED FROM

NORTH SEAL SUS RUN DATA

FROM POSIT C

TO POSIT D

-

RECEIVING SYSTEM ACODAC AT POSIT B

Contents: Pages:

APPENDIX K

-

INTER-HYDROPHONE

TRANSMISSION LOSS DIFFERENCE

COMPUTED FROM

NORTH SEAL SUS RUN DATA

FROM POSIT E

TO POSIT B

-

RECEIVING SYSTEM ACODAC AT POSIT D

Contents: Pages:

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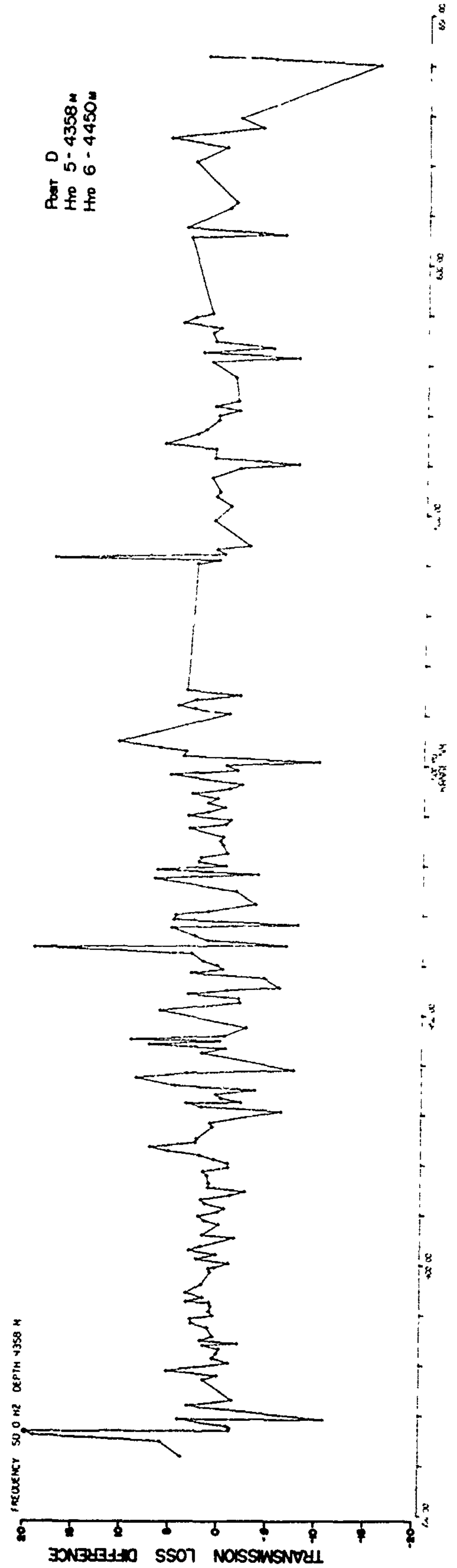

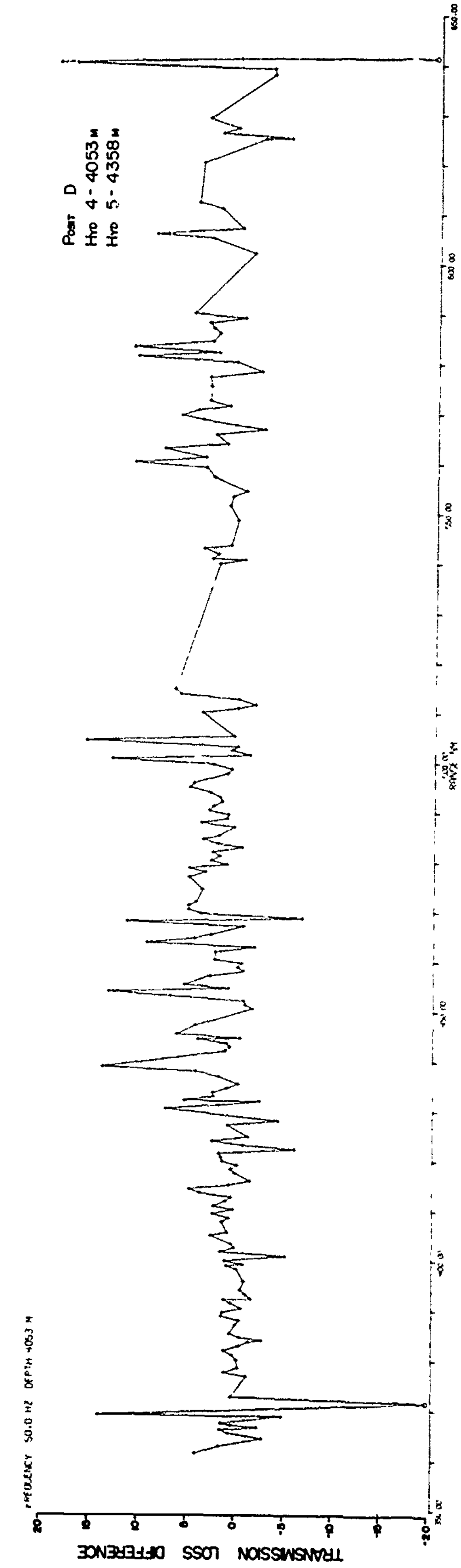

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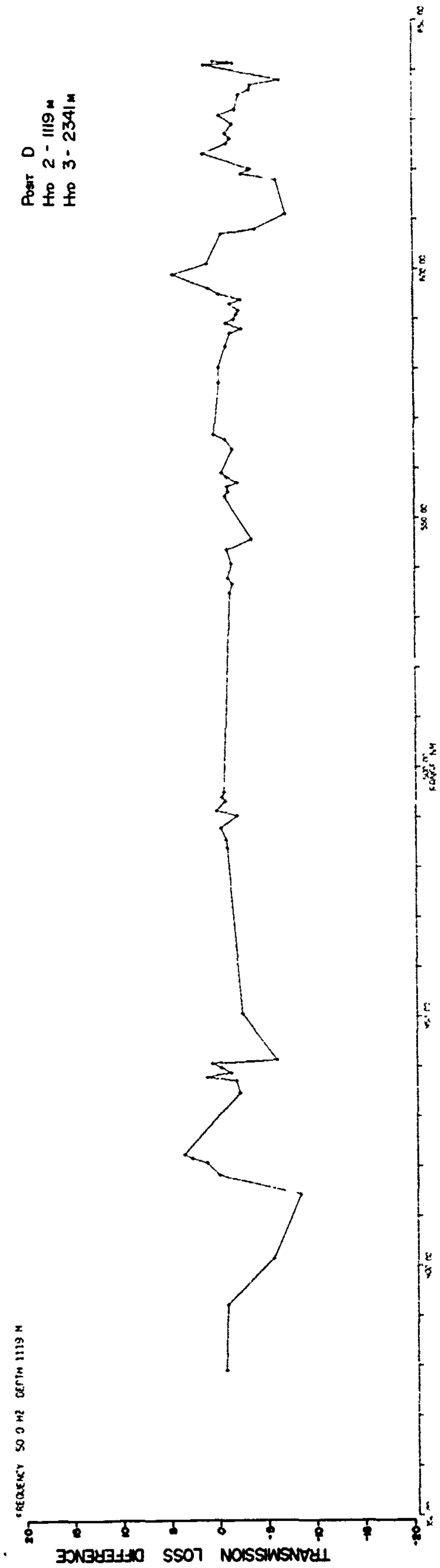

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APPENDIX L

-

INTER-HYDROPHONE

TRANSMISSION LOSS DIFFERENCE

COMPUTED FROM

NORTH SEAL SUS RUN DATA

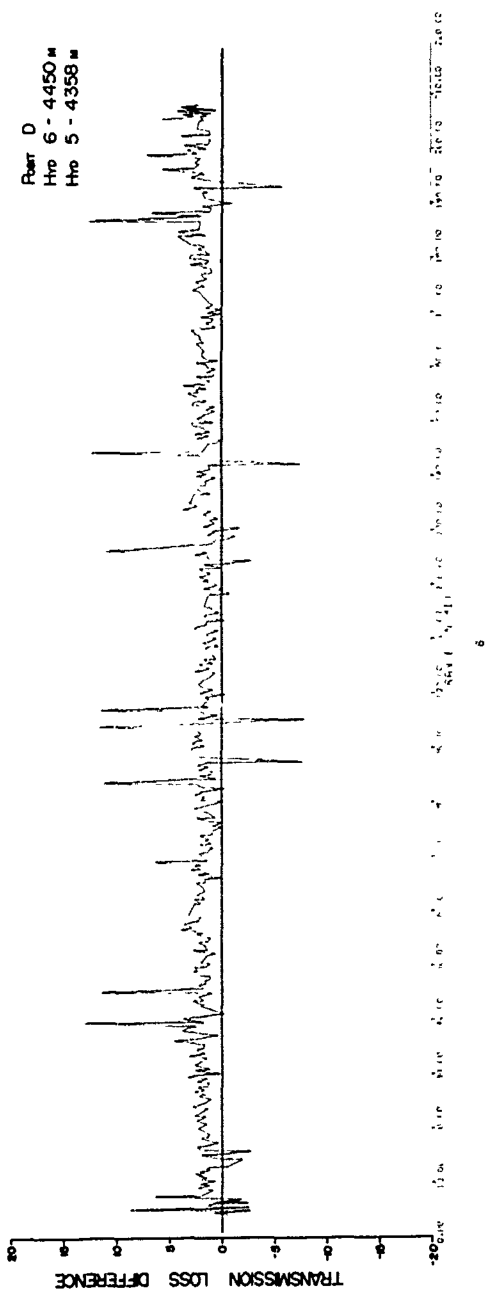
FROM POSIT C

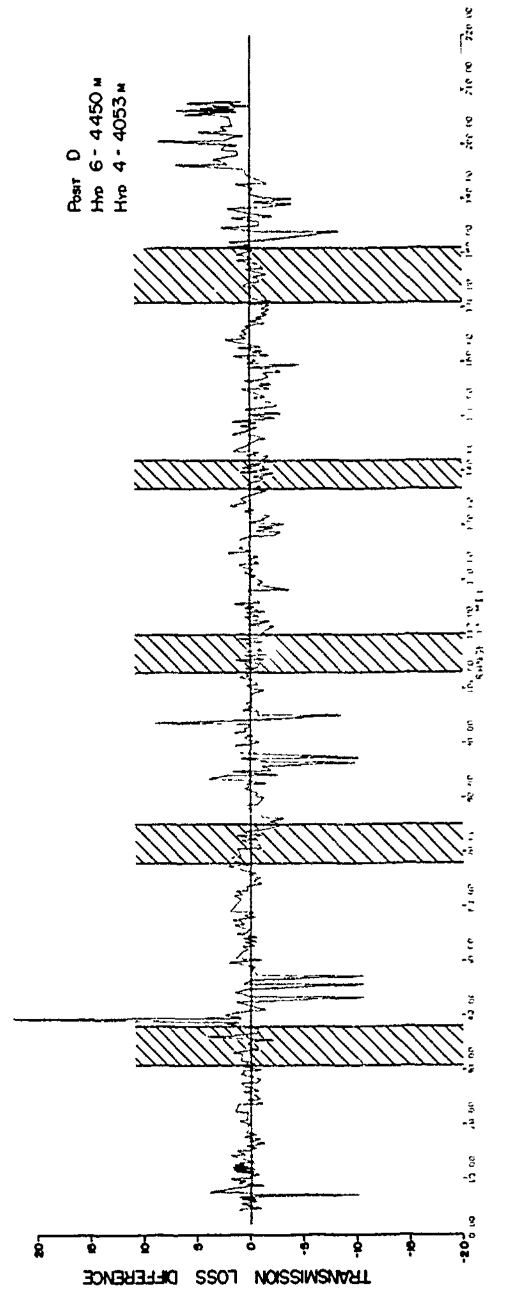
TO POSIT D

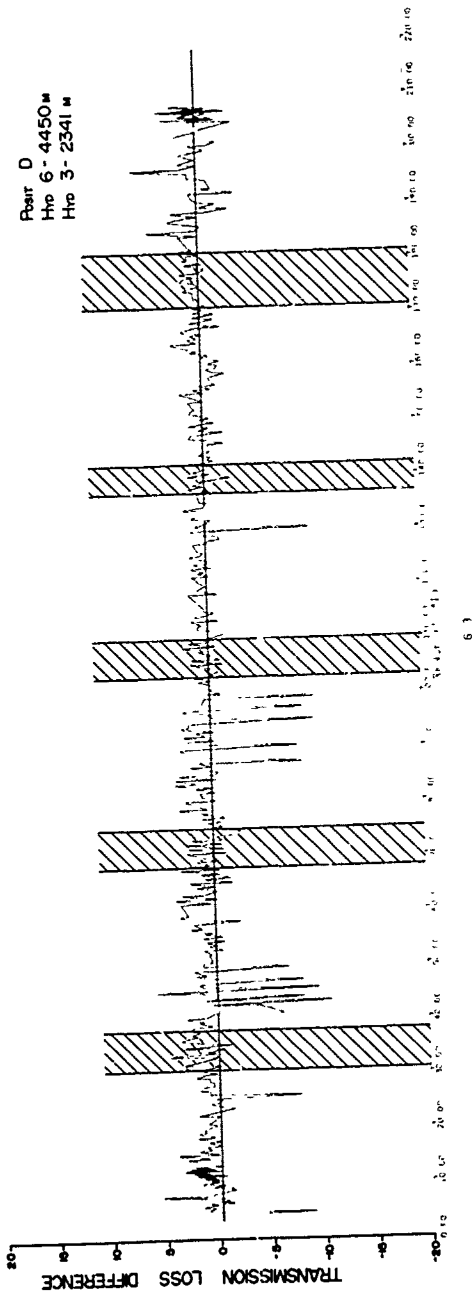
-

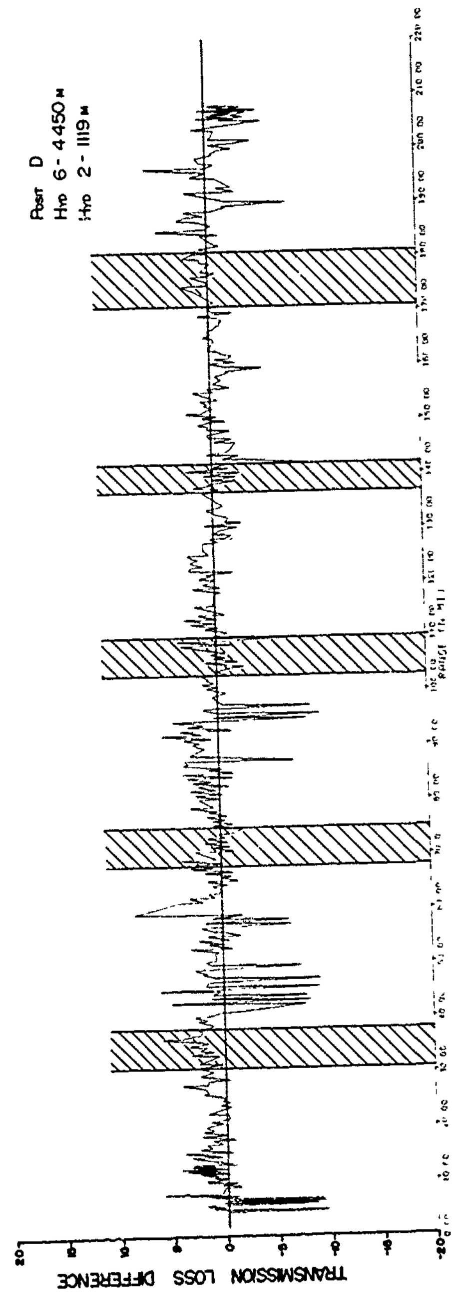
RECEIVING SYSTEM ACODAC AT POSIT D

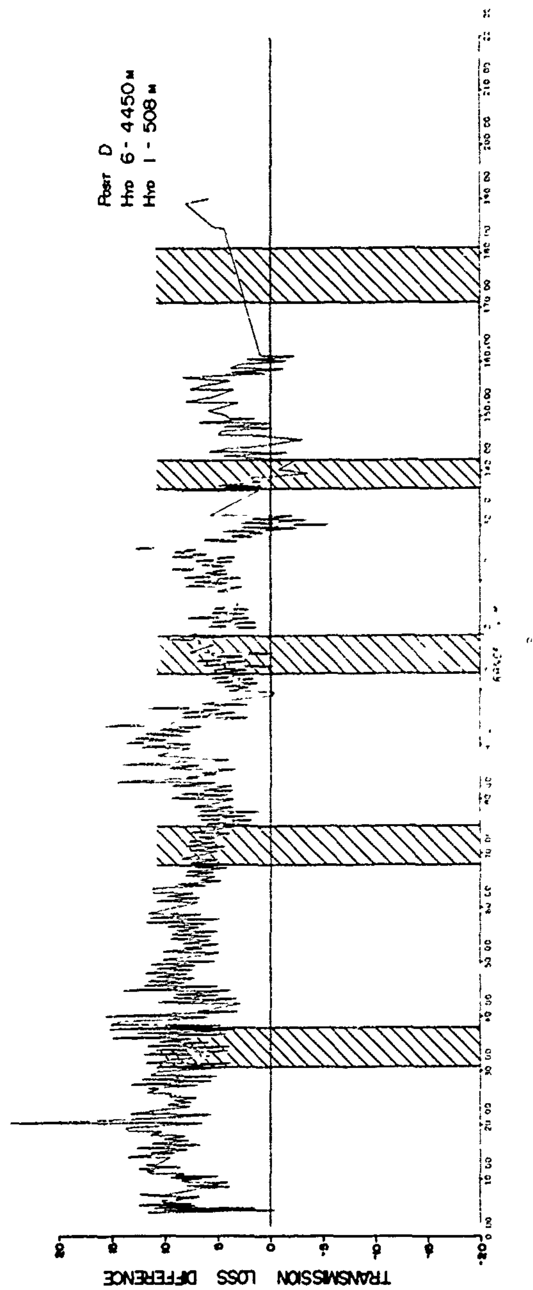
Contents: Pages:

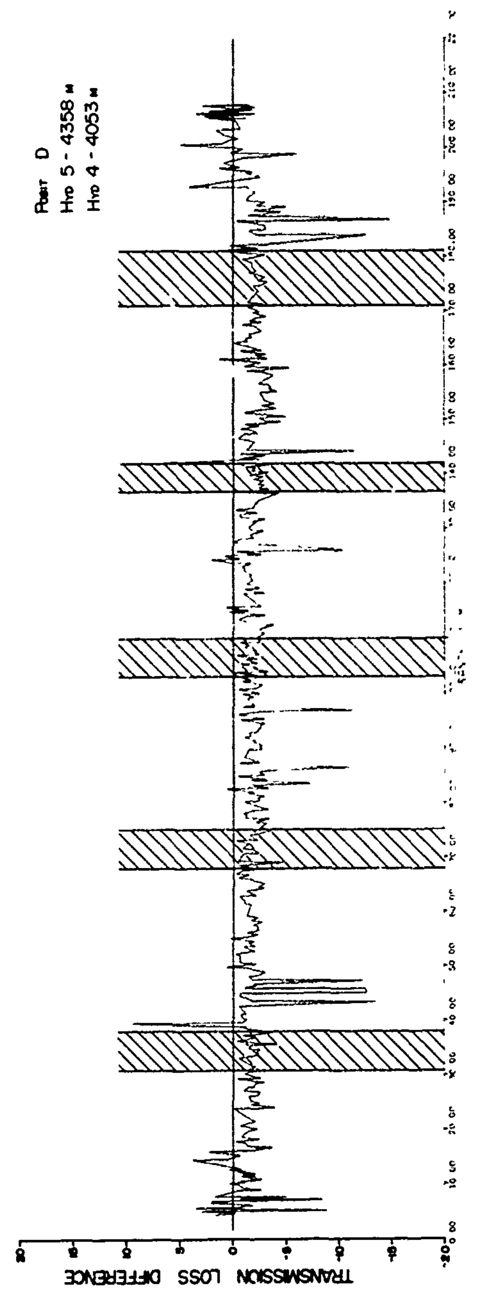

Post D
Hyd 6 - 4450 m
Hyd 5 - 4358 m
TRANSMISSION LOSS DIFFERENCE

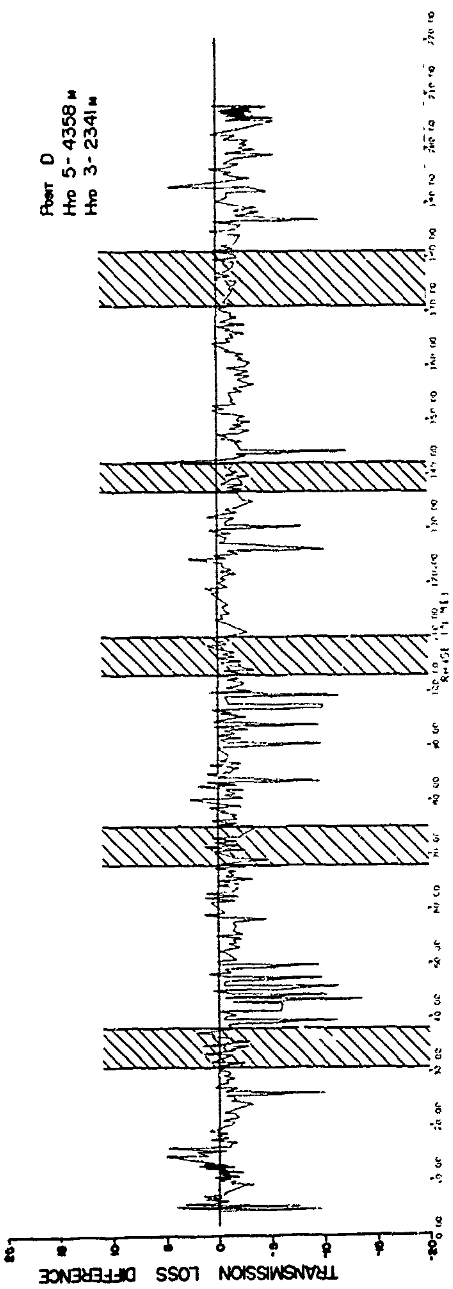

Post D
Hyd 6 - 4450 m
Hyd 4 - 4053 m
TRANSMISSION LOSS DIFFERENCE

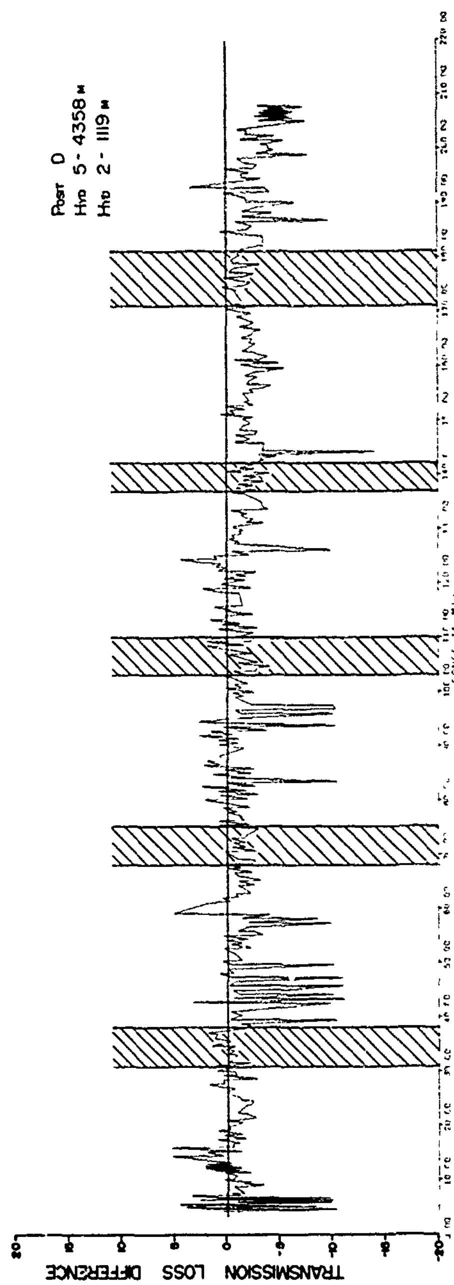

TRANSMISSION LOSS DIFFERENCE

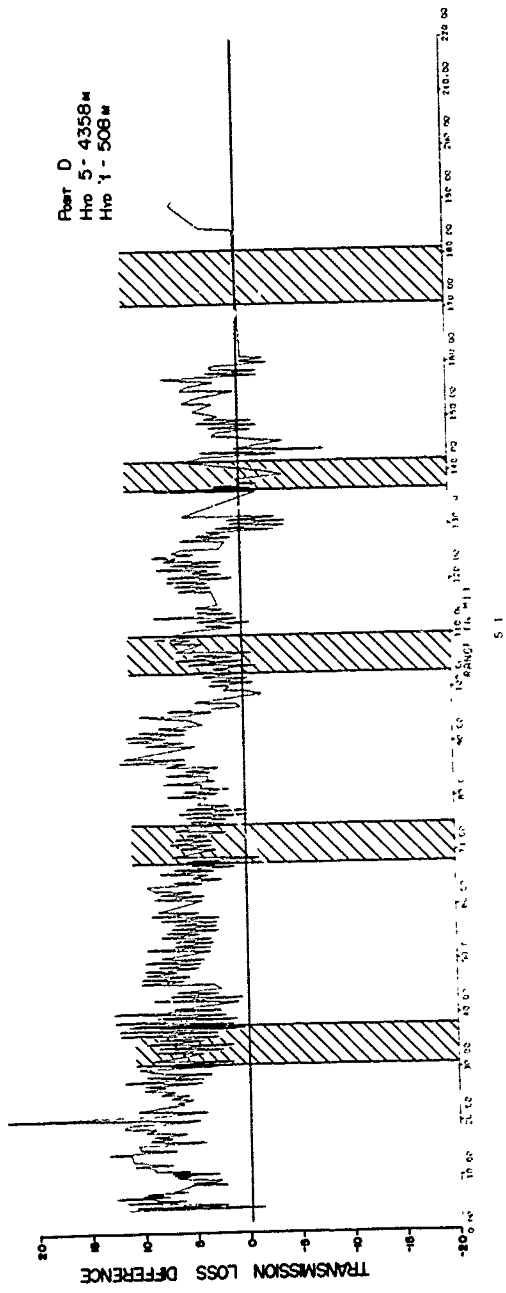

TRANSMISSION LOSS DIFFERENCE

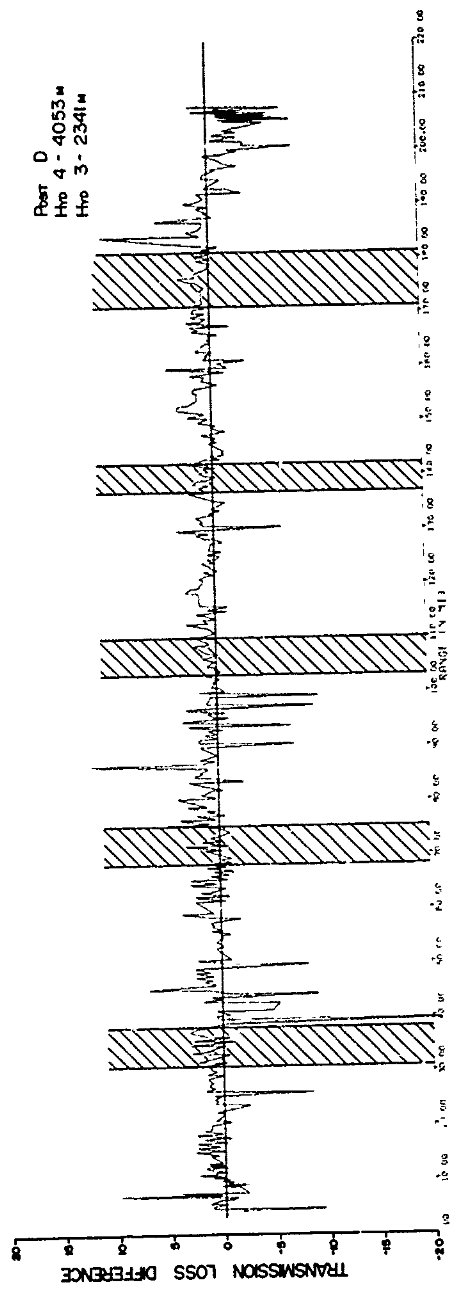

Post D
Hyd 6 - 4450 m
Hyd 1 - 508 m
TRANSMISSION LOSS DIFFERENCE

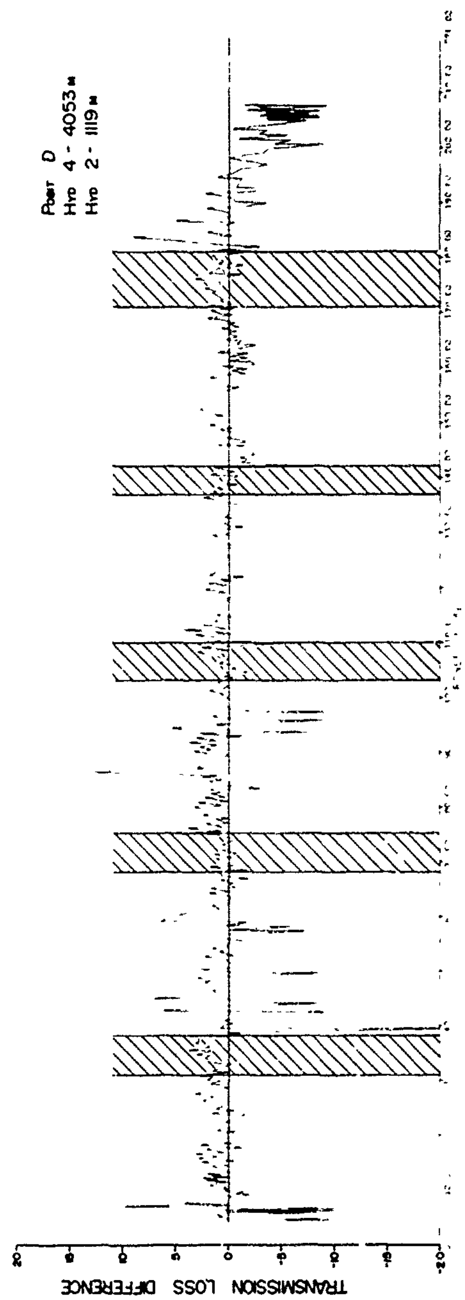

Post D
Hyd 5 - 4358 m
Hyd 4 - 4053 m
TRANSMISSION LOSS DIFFERENCE

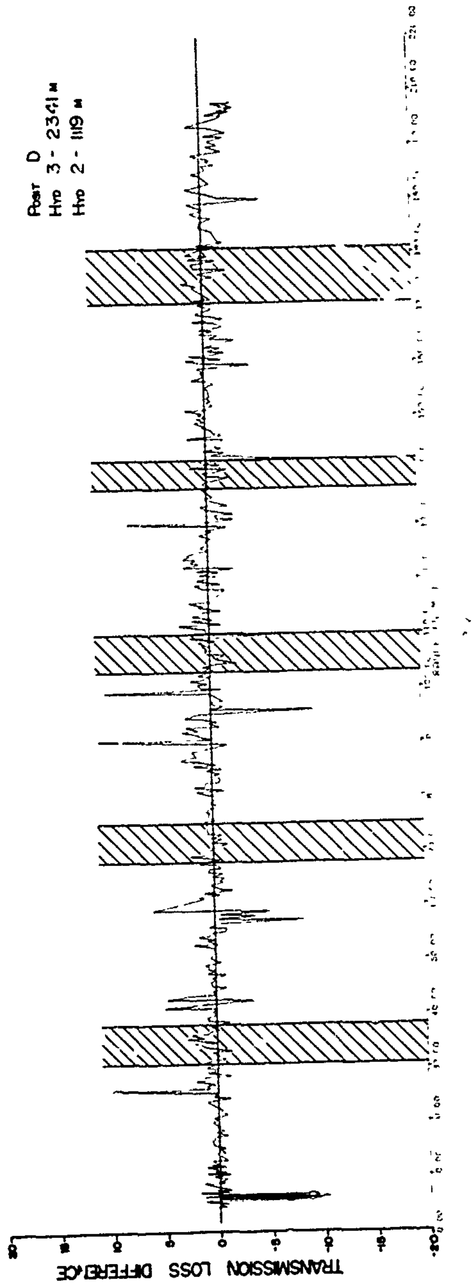

Post D
Hyd 5-4358 M
Hyd 3-2341 M
TRANSMISSION LOSS DIFFERENCE

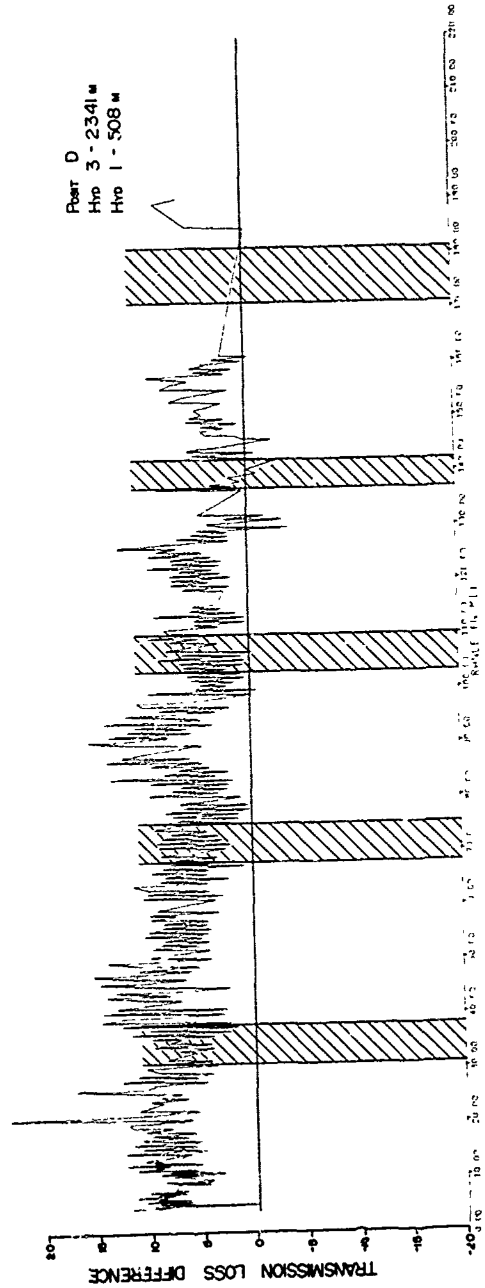

Post D
Hyd 5-4358 M
Hyd 2-1119 M
TRANSMISSION LOSS DIFFERENCE

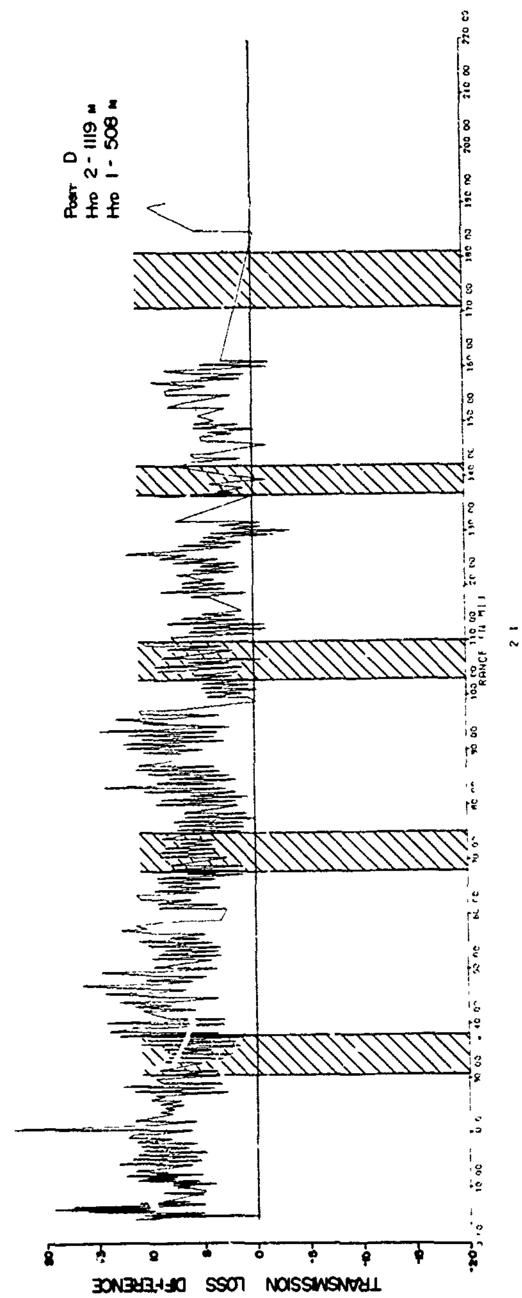

TRANSMISSION LOSS DIFFERENCE


TRANSMISSION LOSS DIFFERENCE

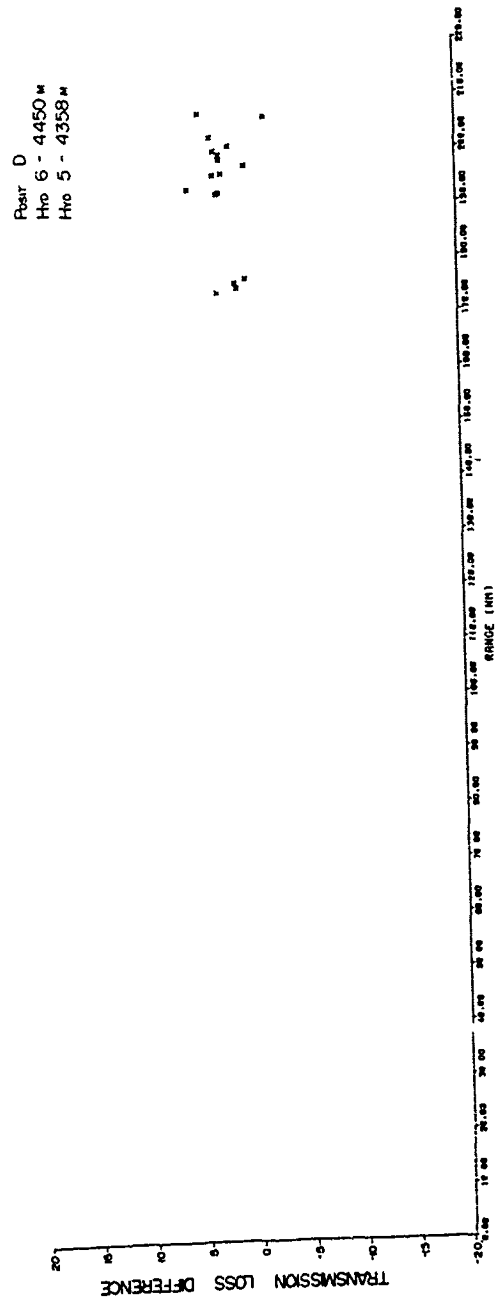

Post D
Hyd 4 - 4053 m
Hyd 2 - 1119 m
20
15
10
5
0
-5
-10
-15
-20
TRANSMISSION LOSS DIFFERENCE


Port D
Hyd 3 - 2341 m
Hyd 2 - 1119 m
TRANSMISSION LOSS DIFFERENCE


Port D
Hyd 3 - 2341 m
Hyd 1 - 508 m
TRANSMISSION LOSS DIFFERENCE


TRANSMISSION LOSS DIFFERENCE

CONFIDENTIAL



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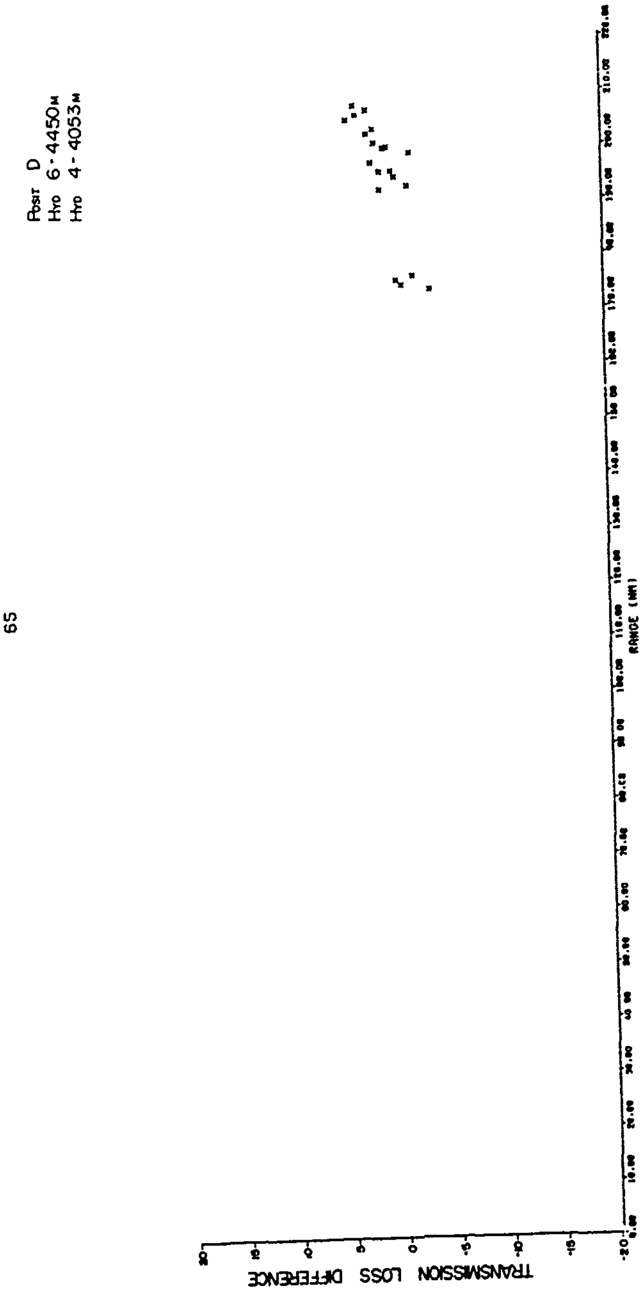

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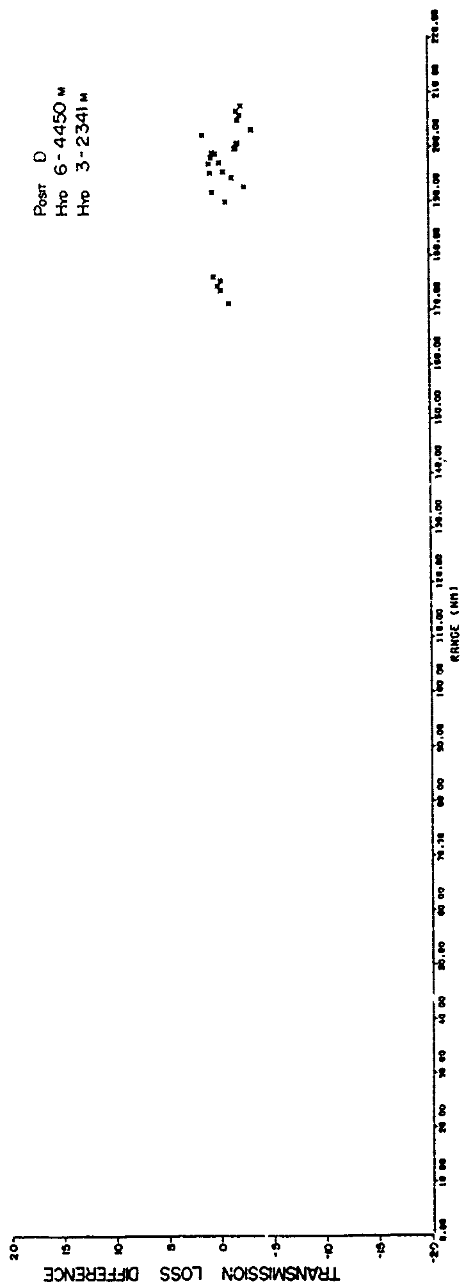
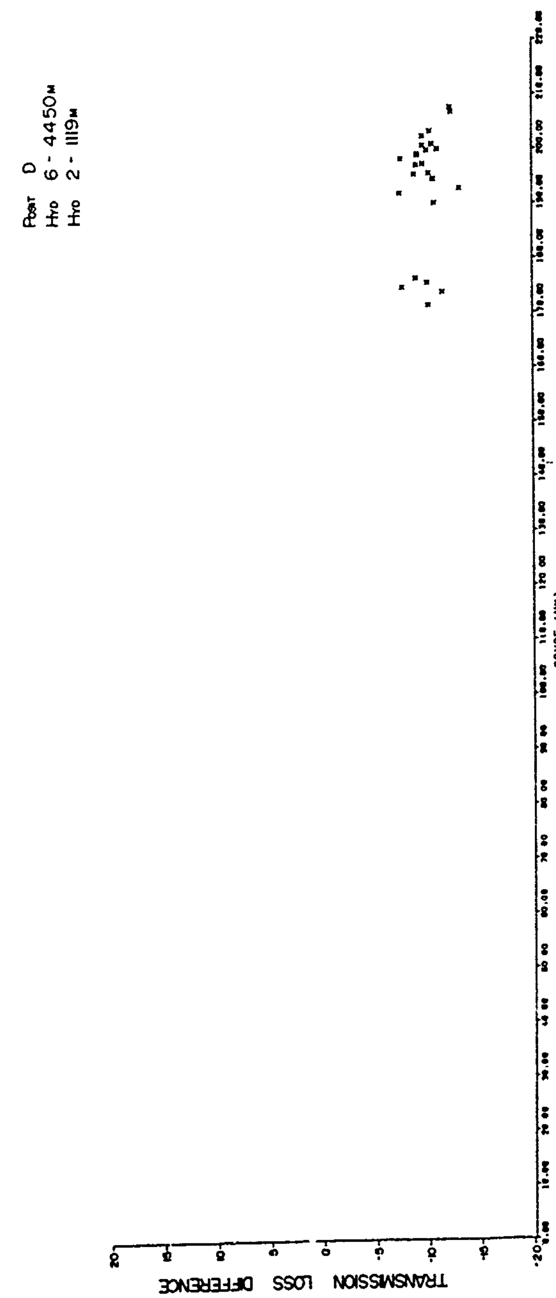
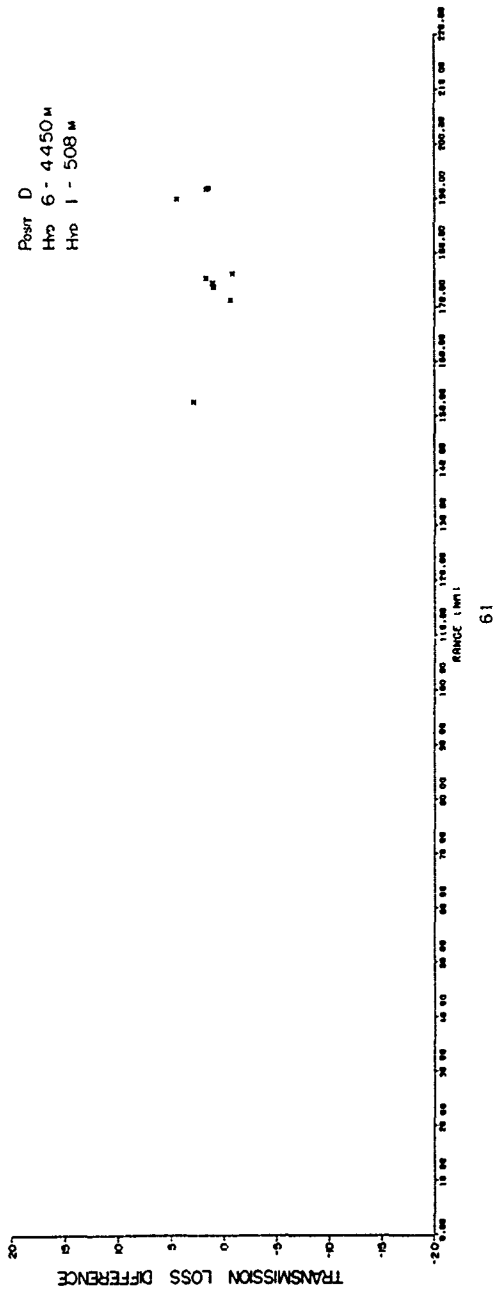
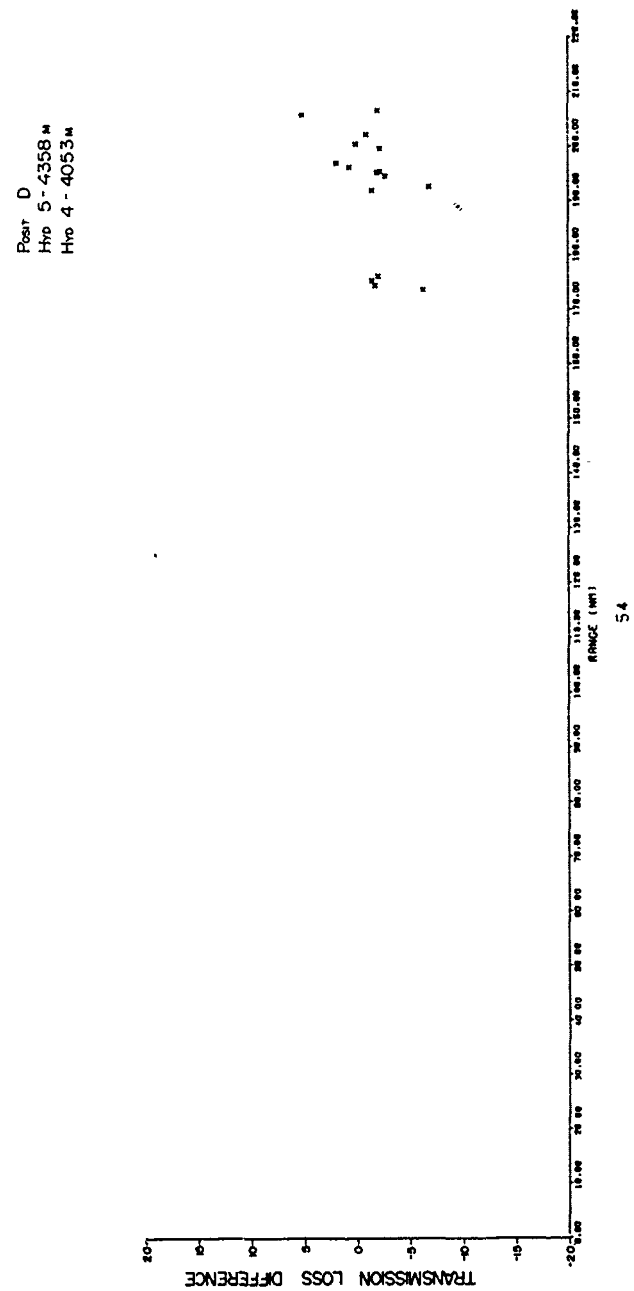

Post D
Hyd 6 - 4450 M
Hyd 3 - 2341 M
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)

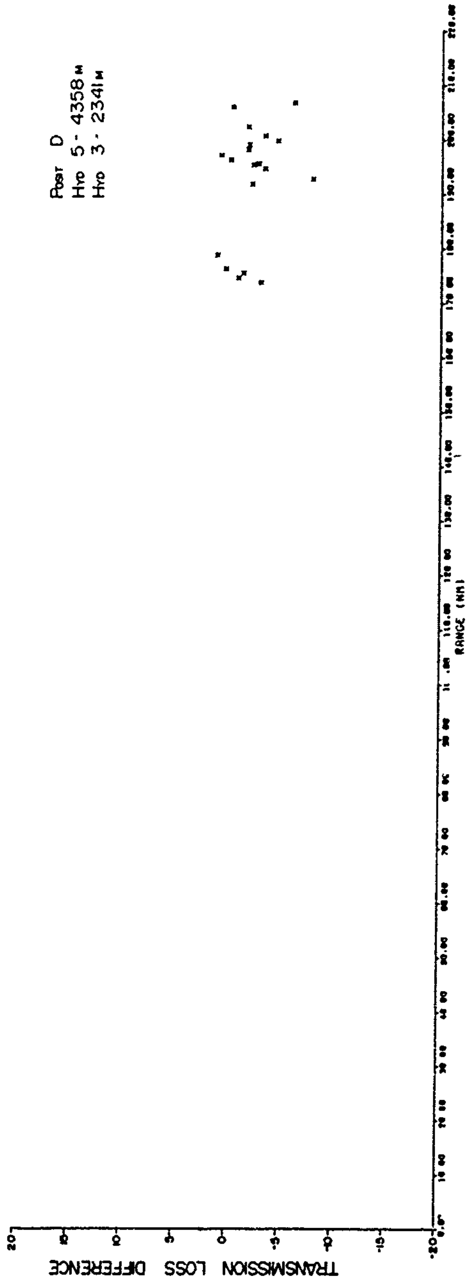
63


Post D
Hyd 6 - 4450M
Hyd 2 - 1119M
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)

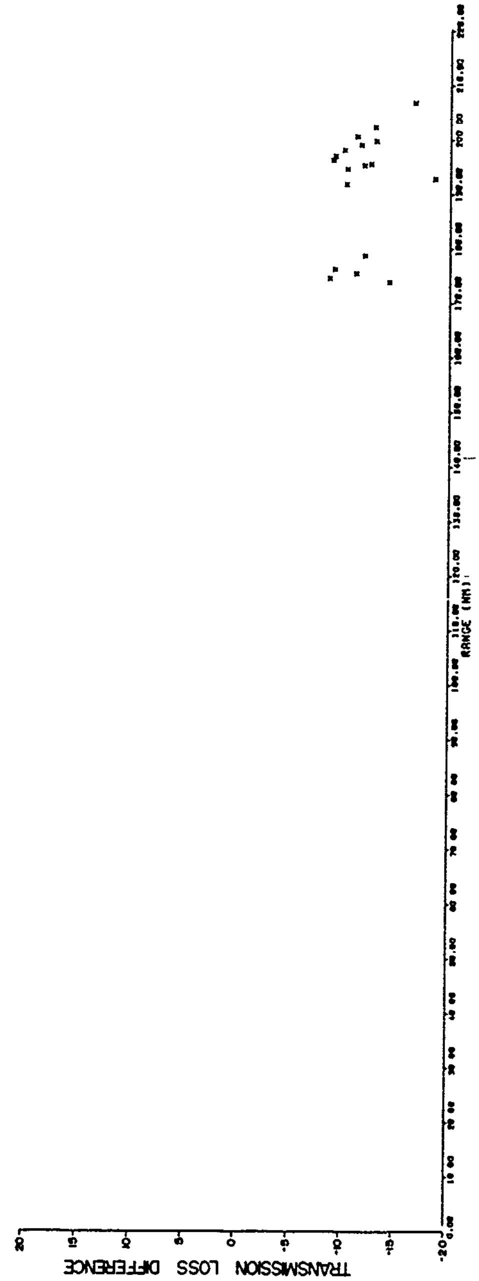
62


Posit D
Hyd 6 - 4450 M
Hyd 1 - 508 M
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)
61

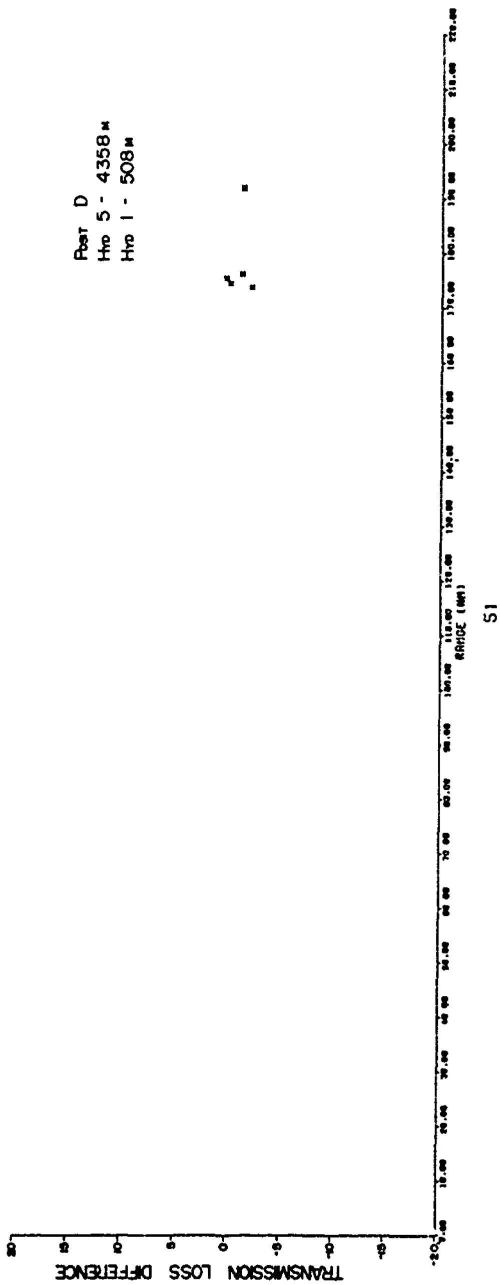

Posit D
Hyd 5 - 4358 M
Hyd 4 - 4053 M
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)
54

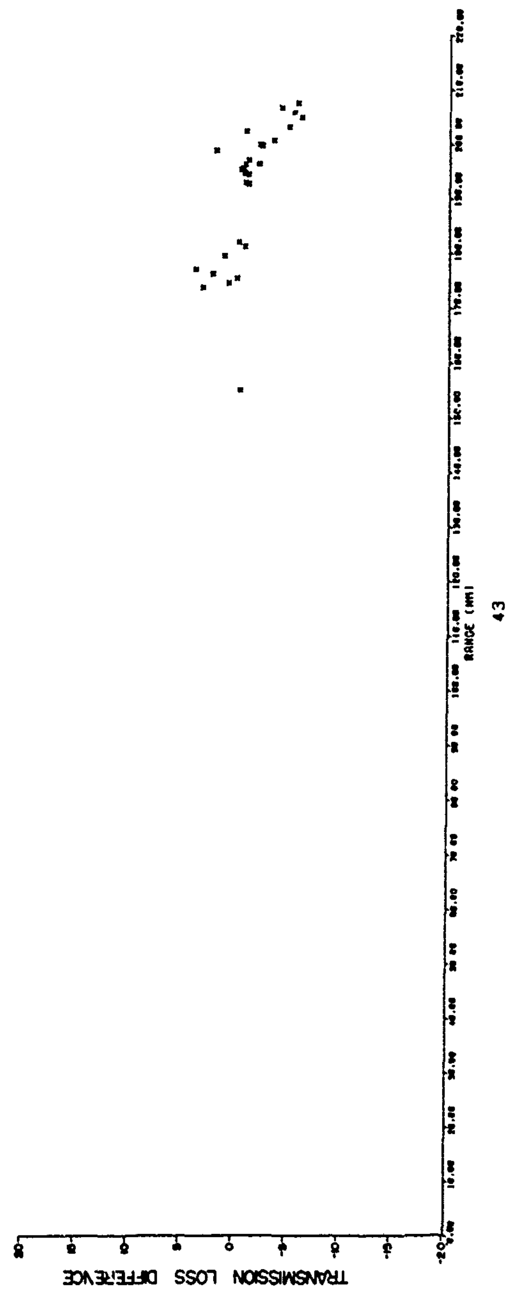

Posit D
Hyd 5 - 4358 M
Hyd 3 - 2341 M
RANGE (NM)
TRANSMISSION LOSS DIFFERENCE

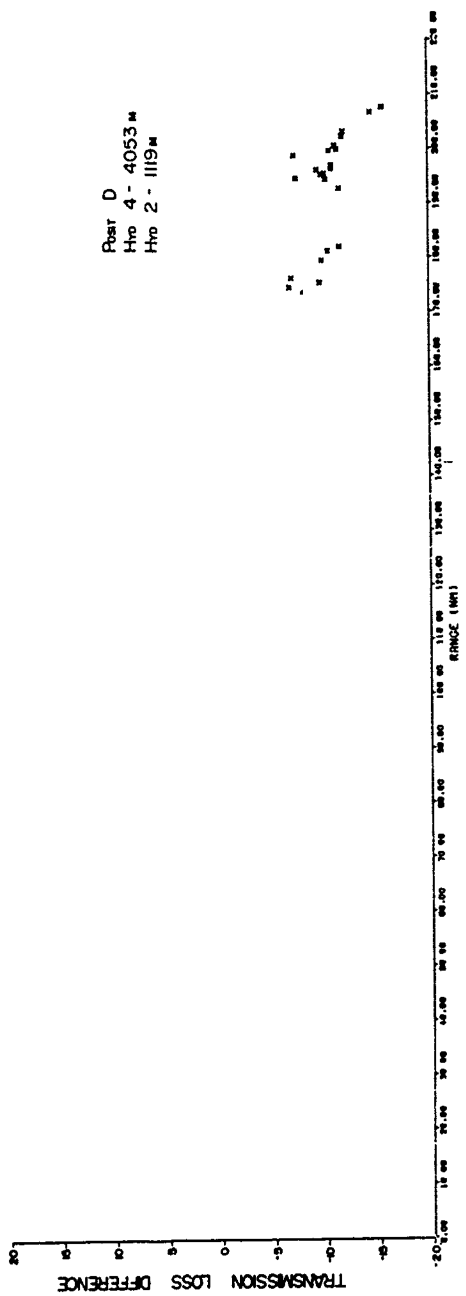
53


Posit D
Hyd 5 - 4358 M
Hyd 2 - 1119 M
RANGE (NM)
TRANSMISSION LOSS DIFFERENCE

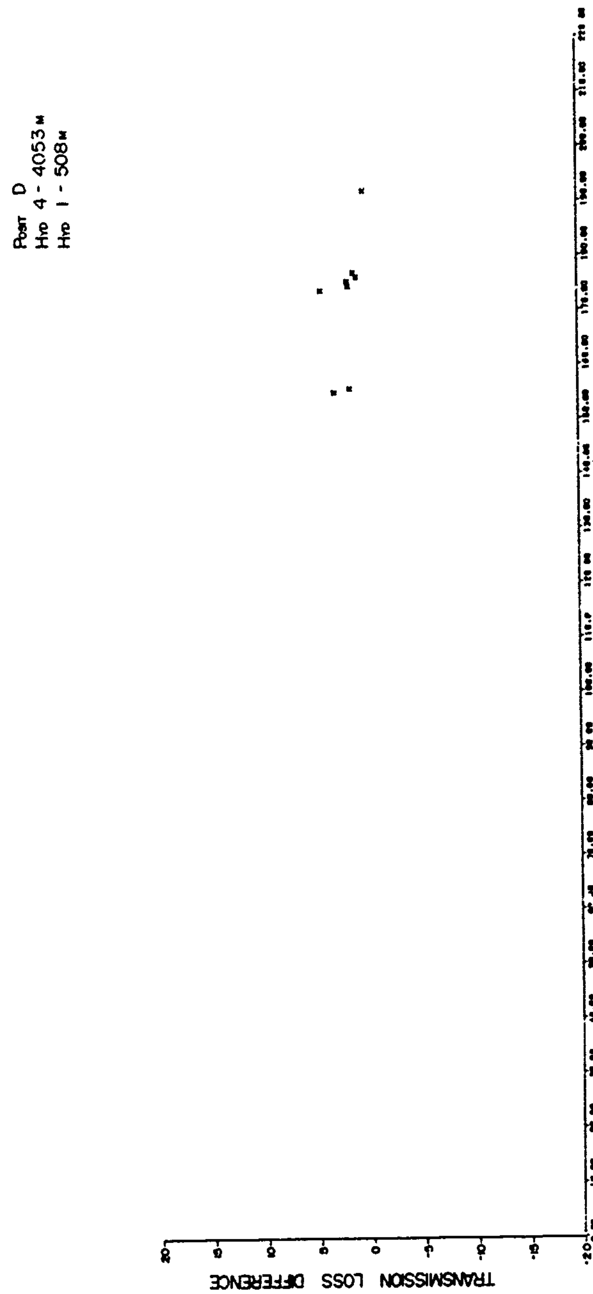
52


TRANSMISSION LOSS DIFFERENCE
RANGE (NM)
51

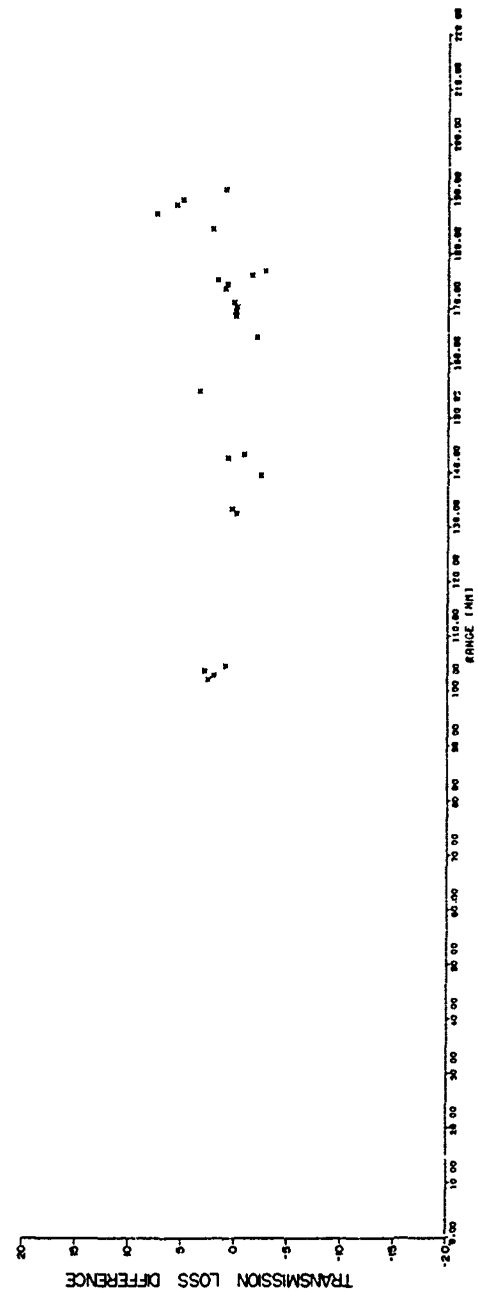

TRANSMISSION LOSS DIFFERENCE
RANGE (NM)
43


Post D
Hyd 4 - 4053M
Hyd 2 - 1119M
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)

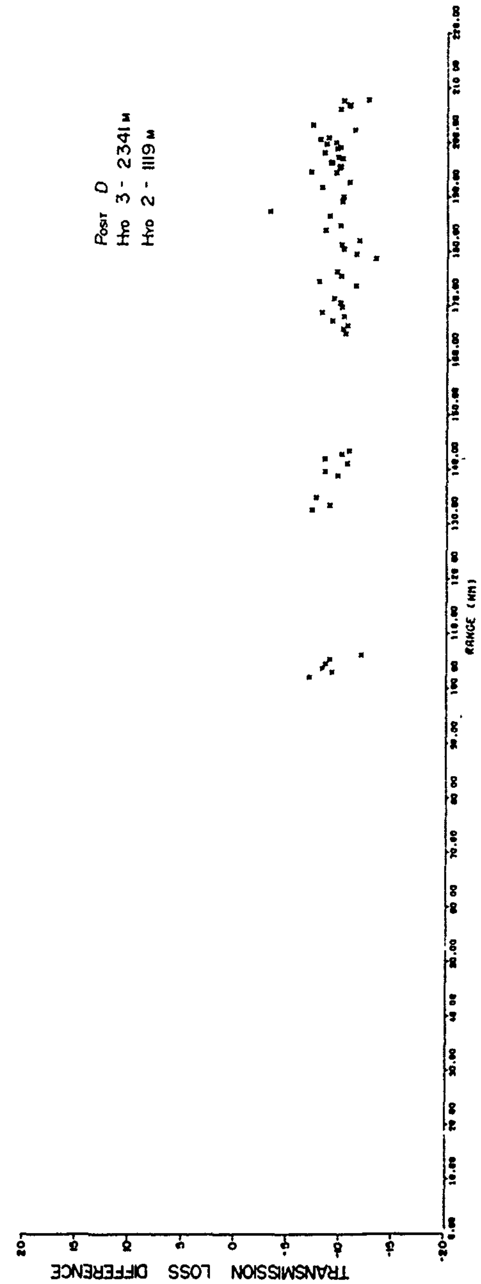
42


Post D
Hyd 4 - 4053M
Hyd 1 - 508M
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)

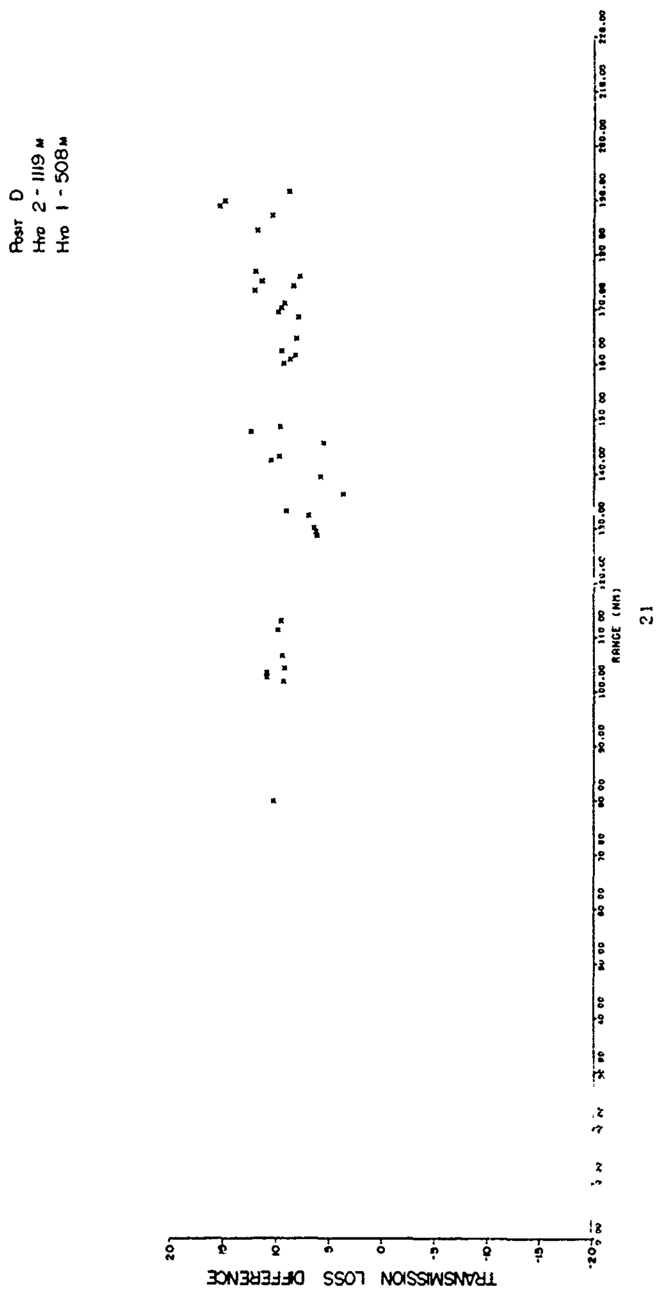
41

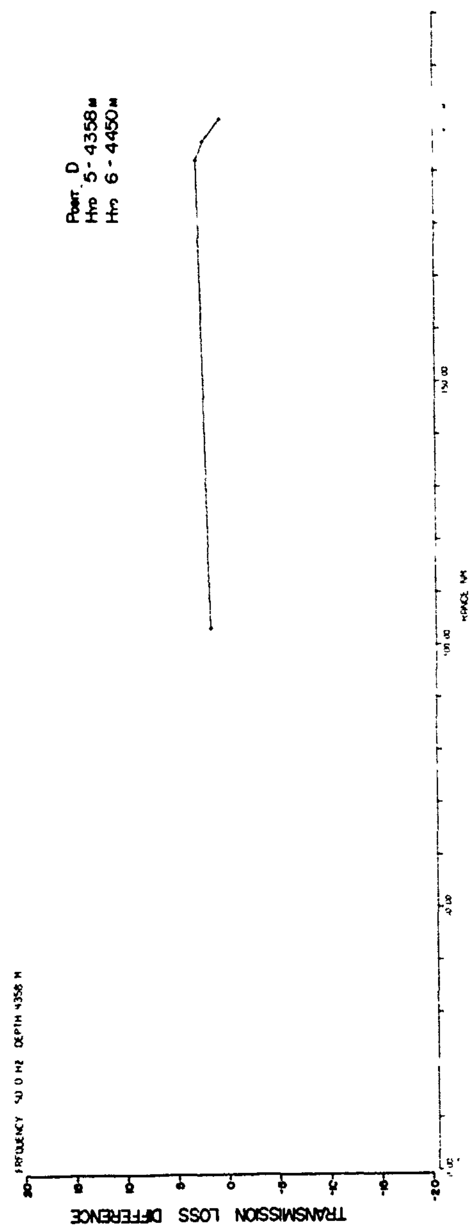

Post D
Hyd 3 - 2341 m
Hyd 1 - 508 m
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)

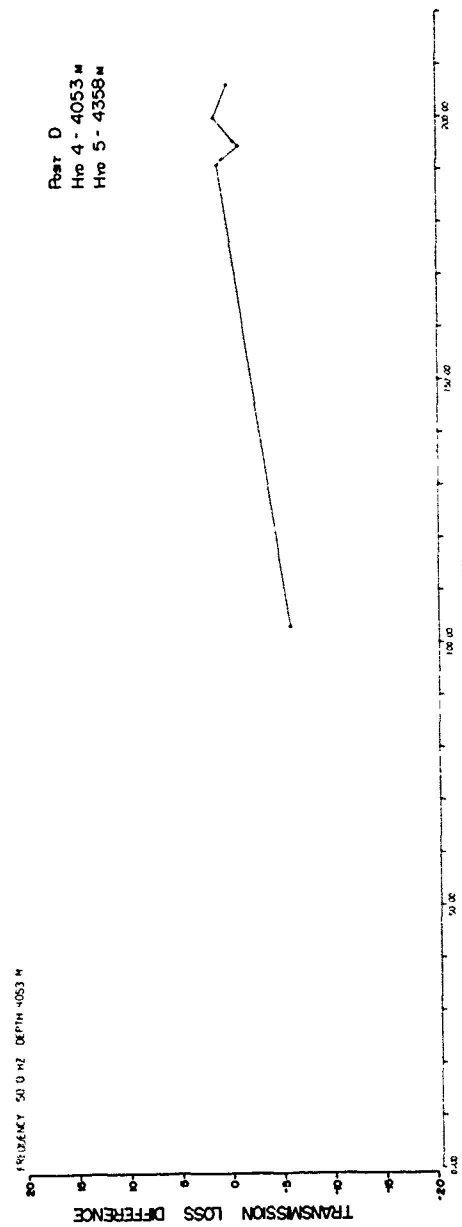
31

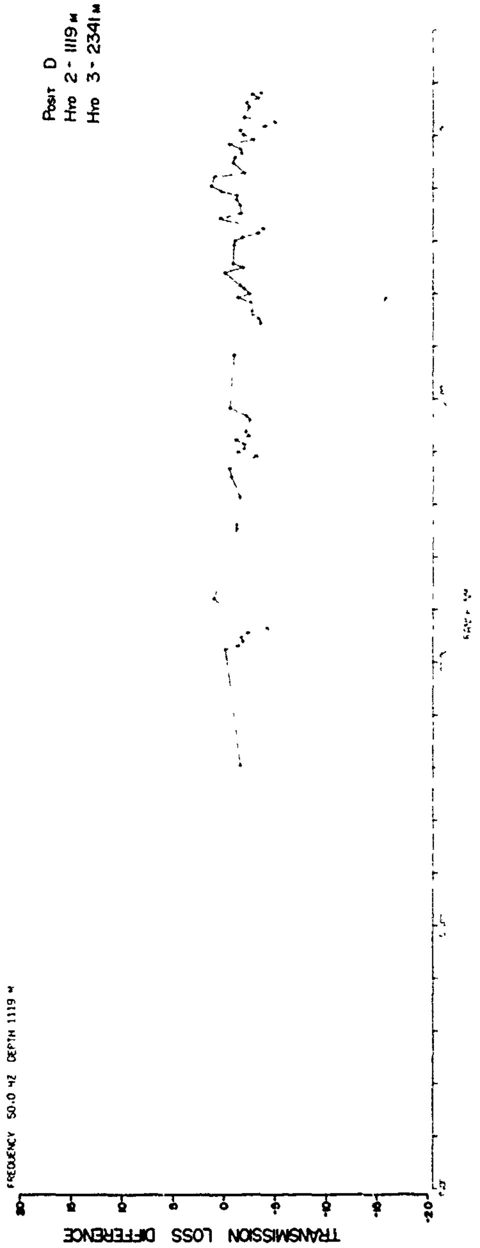

Post D
Hyd 3 - 2341 m
Hyd 2 - 1119 m
TRANSMISSION LOSS DIFFERENCE
RANGE (NM)

32


Posit D
Hyd 2 - 1119 M
Hyd 1 - 508 M
RANGE (NM)
TRANSMISSION LOSS DIFFERENCE


FREQUENCY 50.0 HZ DEPTH 4358 M
TRANSMISSION LOSS DIFFERENCE
RANGE NM


FREQUENCY 50.0 HZ DEPTH 4053 M
TRANSMISSION LOSS DIFFERENCE
RANGE NM



Posit D
Hyd 2 - 1119 m
Hyd 3 - 2341 m
FREQUENCY 50.0 HZ DEPTH 1119 M
TRANSMISSION LOSS DIFFERENCE
20
15
10
5
0
-5
-10
-15
-20

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER (14) HCI-CMC-18540

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) (6) Transmission Loss of Low Frequency Underwater Sound in the Cayman Trough (CHURCH GABBRO Technical Note) (21) (8)

5. TYPE OF REPORT & PERIOD COVERED (9) Technical Report. Nov[redacted]—Dec[redacted] 1972

6. PERFORMING ORG. REPORT NUMBER University of Miami

7. AUTHOR(s) (10) Scott C. Daubin

t.4.

8. CONTRACT OR GRANT NUMBER(s) (15) N00014-67-A-0201-0024 (16) NR-292-117[redacted]

9. PERFORMING ORGANIZATION NAME AND ADDRESS
University of Miami
Rosenstiel School of Marine & Atmospheric Science
10 Rickenbacker Causeway, Miami, Fl. 33149

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Long Range Acoustic Propagation Project

11. CONTROLLING OFFICE NAME AND ADDRESS
Office of Naval Research
Code 102-OSC
Arlington, Virginia 22217

12. REPORT DATE June 1974

13. NUMBER OF PAGES ~~142~~ (12) 149p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. ~~(of this report)~~ CONFIDENTIAL

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Underwater Sound
Transmission Loss
Caribbean
Cayman Trough
Depth Dependence
ACODAC
Low Frequency

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Underwater acoustic propagation loss measurements made in the Cayman Trough as part of the CHURCH GABBRO exercise of Nov-Dec 1972 are reported. 1106 Mk 82-0 SUS set for 91.4 meters were dropped from shipboard and 302 SUS Mk 61-0 set for 18.3 meters and 176 SUS Mk 82-0 set for 91.4 meters were dropped from aircraft. CW projectors were also employed but only the SUS runs proceeded from ENE to WSW along the strike of the Trough; aircraft runs followed a four segment pattern including passages along Trough

over

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S/N 0102-014-6601

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20. axis in WSW and ENE directions. One ACODAC receiving system was located in the approximate center of the Trough, about 140 miles WNW of Montego Bay and a second ACODAC system was located in the SW end of the Trough, a distance of some 355 miles from the first. Each ACODAC deployed six hydrophones throughout the water column, extending from the channel axis to critical depth (and below in one case). ACODACs recorded for a period of 10.6 days, of which SUS runs encompassed about 3 days. TABS and SONOBUOY receiving systems were located about midway between ACODACs during aircraft SUS runs. These systems sampled a total of four shallow depths from 18.3 to 396 meters. Data were reduced by Woods Hole Oceanographic Institution, Applied Research Laboratory of the University of Texas at Austin and the Naval Underwater Systems Center, New London Laboratory. Data reduction systems are described. Transmission loss results are dominated by effects of topography. In the short ranges (out to 160 miles) from the southwest ACODAC a complete SOFAR channel exists, but the convergence zone structure which would be expected in the open ocean shows evidence of being smoothed by the large amount of reflected energy from the lateral topography of the Trough. Reverberation times of up to 1 minute support this hypothesis. At long ranges (beyond 450 miles) the intermediate ridge structure of the Trough baffles acoustic energy, but as range increases out to 600 miles this effect is offset by others, such as bathymetric focussing, which result in an anomalous curve, i.e. the reduction of transmission loss with range. A sharp depth dependence at the receiver was found, sometimes as high as 10 db between adjacent hydrophones separated typically by 400 meters, but this effect was intermittent and a strong function of range, occurring in a regular pattern relative to the locations of the convergence zones.

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WHOI73-59	Tollios, C. D.	THE ACODAC DATA PROCESSING SYSTEM	Woods Hole Oceanographic Institution	730901	AD0773114; ND	U
Unavailable	Russell, J. J.	DOCUMENTATION FOR COMPUTER PROGRAM SUMMARY: A COMPUTER PROGRAM TO SUMMARIZE SOUND SPEED PROFILE DATA	Naval Undersea Center	731001	AD0918907	U
MC001Vol2	Unavailable	CHURCH ANCHOR DATA ANALYSIS PLAN VOL 2 (U)	Maury Center for Ocean Science	731001	ND	U
73-9M7-VERAY-R2	Jones, C. H.	LRAPP VERTICAL ARRAY- PHASE III	Westinghouse Research Laboratories	731105	ADA001130; ND	U
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ARL-TM-73-42	Mitchell, S. K., et al.	QUALITY CONTROL ANALYSIS OF SUS PROCESSING FROM ACODAC DATA	University of Texas, Applied Research Laboratories	731220	ND ADB 000 283	U
Unavailable	Daubin, S. C.	CHURCH GABBRO TECHNICAL NOTE: CONTINUOUS CURRENT PROFILES	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740101	AD0775333	U
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ONR MC-002 VOL. 2; XONICS 885	Unavailable	LONG RANGE ACOUSTIC PROPAGATION PROJECT (LRAPP). SQUARE DEAL DATA ANALYSIS PLAN (U) VOLUME 2 - ANNEXES	Maury Center for Ocean Science; Xonics, Inc.	740101	ND	U
ARL-TM-74-12	Groman, R. O., et al.	SPECIAL HARDWARE FOR ARL ANALYSIS OF ACODAC DATA	University of Texas, Applied Research Laboratories	740314	ADA000295; ND	U
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HCI-CMC-18343	Daubin, S. C.	AMBIENT NOISE IN THE NORTHWEST CARIBBEAN SEA (CHURCH GABBRO TECHNICAL NOTE) (U)	University of Miami, Rosenstiel School of Marine and Atmospheric Science	740601	ND	U
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